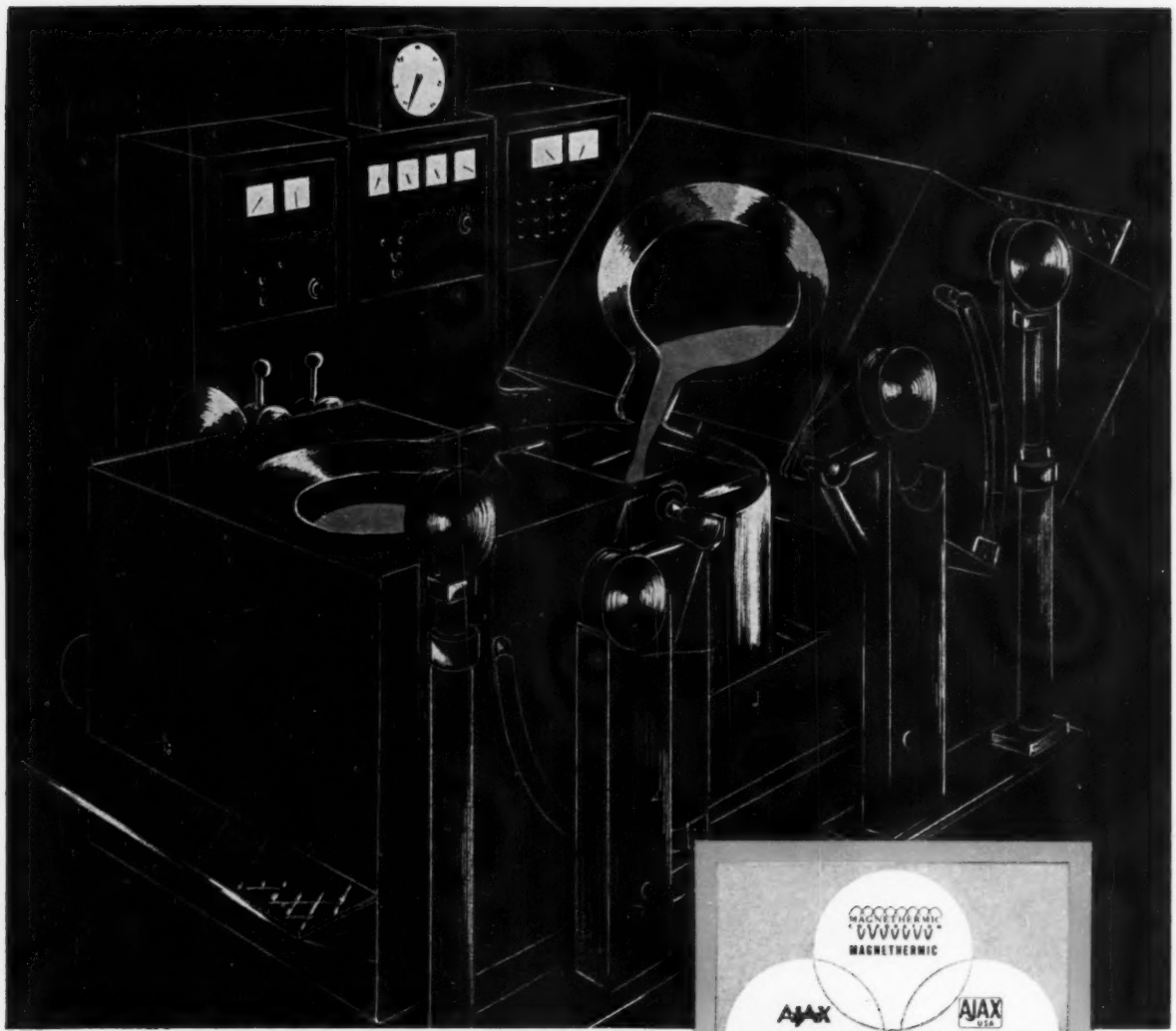
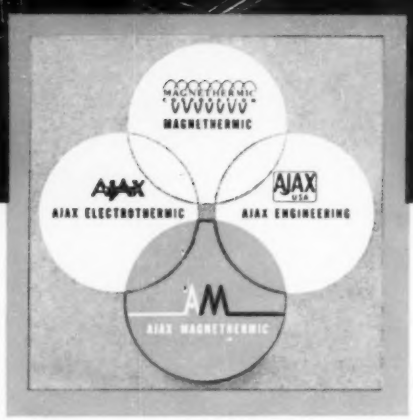
December
1960

Metal Progress



These twin 1000-lb. melting furnaces prepare copper for metal powder at the St. John's, Michigan, plant of Federal-Mogul-Bower Bearings, Inc.



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Metal Progress

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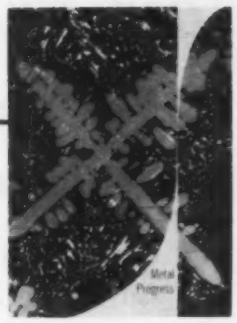

COVER: The scarlet cross is a primary dendrite of cuprous oxide in a copper-oxygen alloy, photographed in polarized light. Prepared by L. E. SAMUELS and G. W. WESTBURY, Defence Standards Laboratories, Australia, it won a prize in the 1959 A.S.M. Metallographic Exhibit.

Technical News in Brief

Steel With 9% Nickel Stays Tough at −320° F. . . . Electrolytic Machining Shapes Hard Metals . . . Zinc Protects Hot Columbium . . . Auto Industry Looks at Stretch-Forming . . . Gas Pressure Compacts Hot Uranium Nitride . . . Auto Makers Trim Costs With Magnesium Die Castings . . . Study Reveals Best Way to Paint Welds . . . Got Any Use for Gold? . . . Materials Progress in Nonmetallics 65

Engineering Articles

Spinning Makes Stronger Rocket Cases, by Lewis E. Zwissler 71

When many early rocket cases failed in weld zones, designers attempted to minimize the number of welds. Shear spinning appears to be a good method for fabricating surfaces of revolution which would require a minimum of welding for rocket cases. (G13, T2p; AY)*

Does Silicon Accelerate Decarburization? by Peter Payson 78

Not in medium-carbon alloy steels, according to the author. Silicon actually promotes separation of ferrite from austenite on cooling, and the excess ferrite at the surface of steels high in silicon has been attributed erroneously to decarburization. Elements added for more hardenability (Cr and Mo, for example) will negate this effect. (J4a, J5, 2-60; AY, *Si*)

Magnesium Die Castings for Automobiles, by A. R. Tinetti 82

Seven types of parts weighing up to ½ lb. are being cast of AZ 91 B magnesium alloy in cold chamber die-casting machines. Larger parts are being considered for the future. (E13, T21; Mg)

Structure of Carburized and Carbo-Nitrided Cases, by S. R. Rouze and W. L. Grube 86

Extensive studies of case hardened steels with the electron microscope have revealed three types of surface conditions – normal, overcarburized, and decarburized. (M27, J28g, J28m; AY)

Constricted-Arc Process Cuts Metals Under Water, by C. H. Wodtke 91

Torches of special design are being used successfully in the maintenance of nuclear reactors. Cutting is rapid and because the torch and work are completely submerged, spatter is confined and release of radioactivity to the air is reduced to a safe level. (G22)

Astroloy – a Superalloy for 1900° F. Use, by J. F. Barker, W. H. Couts, Jr., and R. J. Morris 94

This latest addition to the ranks of nickel-base superalloys contains 4.50% Al, 3.5% Ti and 0.03% B. It has excellent yield strength and stress-to-rupture properties, and can be readily shaped and welded while in the annealed condition.

A Century-Old Test of Metal, by Harold J. Roast 99

Historical note on the casting of "Big Ben" 102 years ago at the Whitechapel Bell Foundry in London.

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**The coding symbols refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

How grid tray life was increased from 4 to 72 months

Electro-Alloys' knowledge of thermal fatigue extends service life 1700%

Figure 1 shows a grid tray used to move a solid cube of steel through a heat-treat furnace where side burners directed flame over the top of the tray, Figure 2. After 3-5 months' service, this tray would distort and fail, Figure 3. A photographic close-up of the failure is shown in Figure 4.

The user assumed the failure was due to inadequate pushing strength. With strengthened pushing ribs, the redesigned tray lasted only 2-3 months, half as long as the original design.

In view of this behavior, the user requested an Electro-Alloys design evaluation. The results are shown in Figure 5. *This new tray has a service life of 5-7 years!*

Pinpointing cause of thermal-fatigue failure

Electro-Alloys found that the *original tray* had been *overdesigned*. Extensive knowledge of the subtleties of thermal fatigue led to this conclusion.

Study of the furnace operation showed that the zones of heating and a heavy cooling concentration were the real causes of tray failure. They acted in this way:

On entry into the furnace, outside members of the tray heated more rapidly than inside members. As a result, expansion of these outside members was restricted by the cooler inside members. This set the stage for compression failure of outside members.

Farther in the furnace, inside members came up to temperature. But outside members had already forged in and were undersized. Now, expanding inside members subjected outside members to tensile stresses. This double reversal of stresses, compression then tension, during every cycle soon produced failure.

Any attempt to strengthen these outside members results in earlier failure because the increased mass leads to the metal fighting itself even more.

New design solves problem

The new design, Figure 5, called for raising the transverse ribs. This allowed the heated air to pass under the heavy die block. Through this simple change, it was possible to bring the die block to temperature more quickly and to eliminate the high temperature differential between outside and inside members of the tray.

The result is a 1700% increase in service from each tray.

Avoiding expensive thermal-fatigue pitfalls

Users and designers of heat-resistant castings are vulnerable, generally, to two pitfalls that lead to losses in service life and operating economy:

a. Assuming that an alloy operating well at 2000°F. will work just as well in a different application whose maximum temperature is only 1700°F.

b. Too much faith in the calculation of applied stresses as the measure of the casting's ability to withstand service conditions. This is reflected by increasing the size or number of restricting members . . . braces, gussets and tie rods.

These pitfalls are a natural outgrowth of the lack of information on thermal fatigue . . . the cause of 90% of all failures of heat-resistant castings.

Electro-Alloys is recognized as the leading authority on thermal fatigue and high-alloy casting design. Hundreds of case histories — such as the one reported here — and the widely published test data emanating from the Research Laboratory at Mahwah, N. J., are evidence of this.

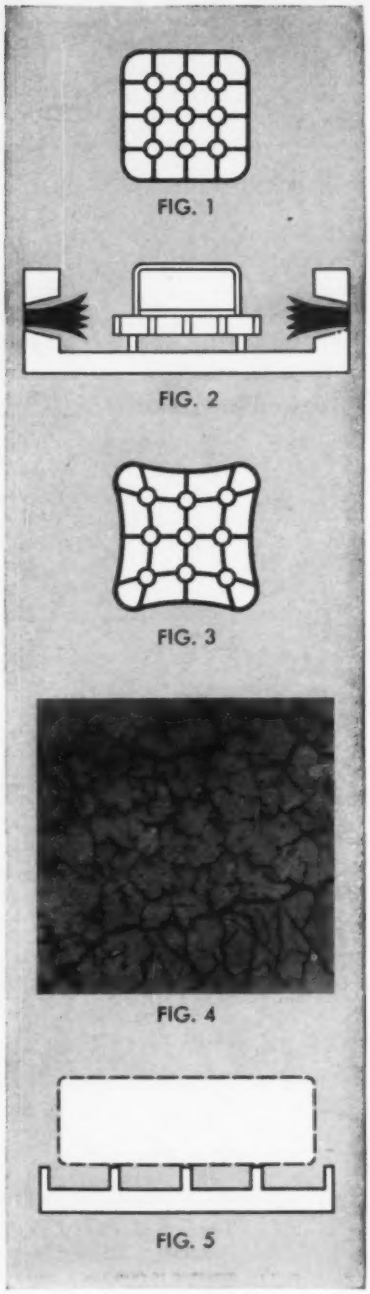

FIG. 1

FIG. 2

FIG. 3

FIG. 4

FIG. 5

● *Most recent of these reports is "The Mechanism of Thermal Fatigue," by H. S. Avery. Copies of this study are available on request. Simply write to Electro-Alloys Division, 20112 Taylor Rd., Elyria, Ohio.*

American Brake Shoe Company

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Metal Progress

High-Strength Steel Sheet (300 M), by J. C. Chang, F. J. Herr and J. W. Sweet 101

Heat treated to 270,000 psi. tensile strength, it retains 7% elongation at subzero temperatures and 230,000 psi. ultimate at 600° F. Proper welding techniques are necessary to achieve these properties in the joints of missile cases. (Q-general, 3-70; AY, 4-53)

Color Finishing of Galvanized Steel, Staff Report 105

Panels for prefabricated metal buildings are formed from galvanized strip and then primed with a bond coat which anchors a pigmented vinyl coating to give a long-lasting finish. (G11, L26n; ST, Zn, 8-65)

Nondestructive Testing of Small Tubing, by J. R. Grieve and A. M. Bounds 110

This article compares eight nondestructive testing methods – visual, boroscopic, eddy current, dye penetrant, magnetic particle, ultrasonic, radiographic, and hydrostatic. Though eddy current testing is considered to be the most versatile, no one test can give a complete answer by itself. (S13; 4-60)

Bimetallic Heat Exchanger Tubes Solve Dual Corrosion Problem, by W. G. Ashbaugh and S. E. Doughty 115

Copper on the outside prevents pitting and stress-corrosion cracking caused by brackish cooling water; stainless steel on the inside withstands corrosive action of chemicals being processed. (R1d, R2j, W13b, 17-57; Cu, SS, 4-60)

Metals Reinforced With Fibers, by D. L. McDanels, R. W. Jech, and J. W. Weeton 118

Experiments with composites made up of tungsten wires in a copper matrix indicate that their strengths are directly proportional to the volume percentages and tensile strengths of the tungsten wires. If whiskers are used instead of wires, composites with tensile strengths of over 1,000,000 psi. may some day be available. (H17; Cu, W, 14-61)

Good Design Pays Off in Zinc and Gray Iron Castings 122

Emphasis on good design and careful selection of the method by which parts are made can lead to economies in production and a more useful product. Pictured here are castings that were conceived with these ideas in mind. (T-general, 17-57; CI-n, Zn, 5-60, 5-61)

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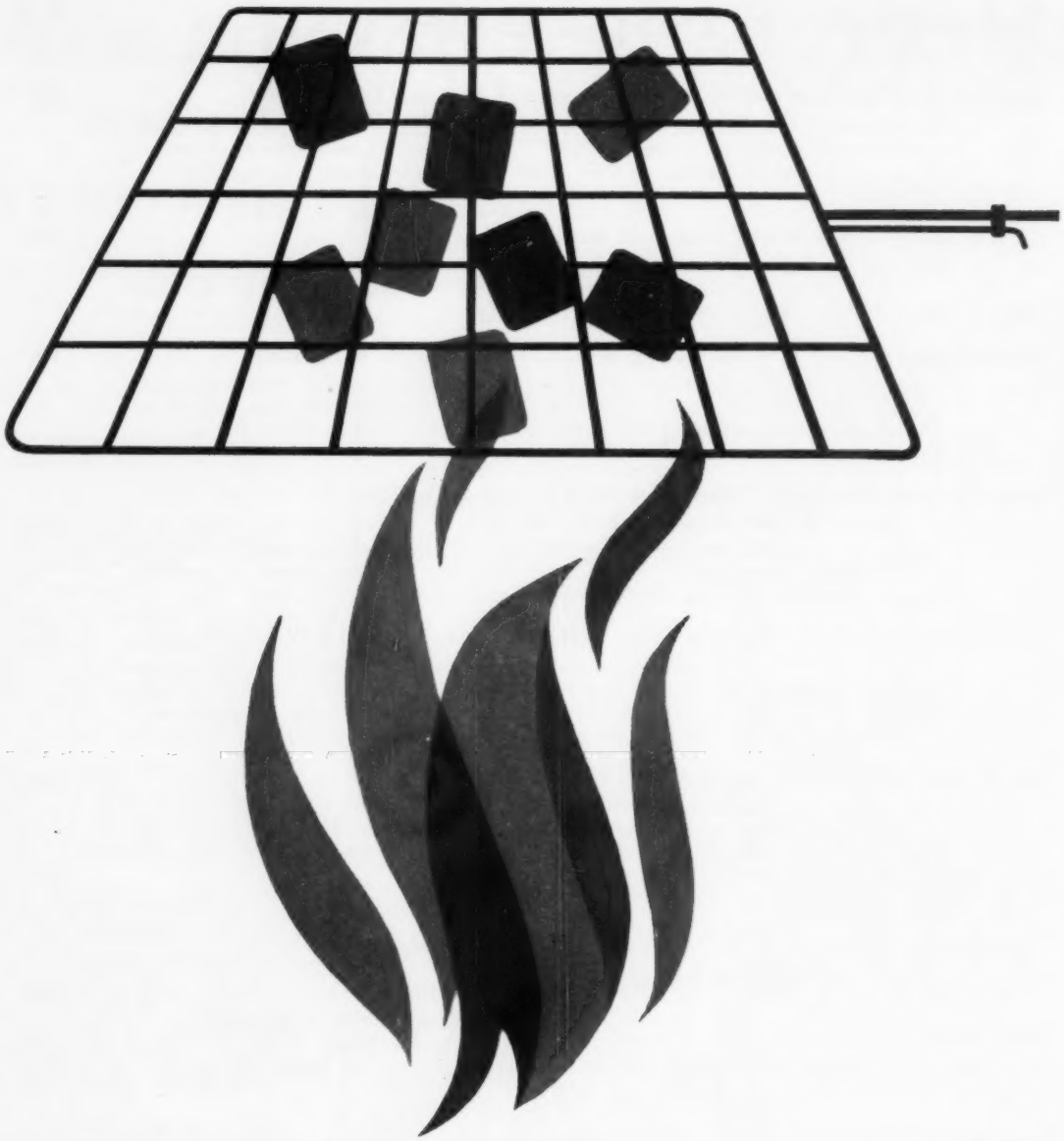

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PRESS BREAKS

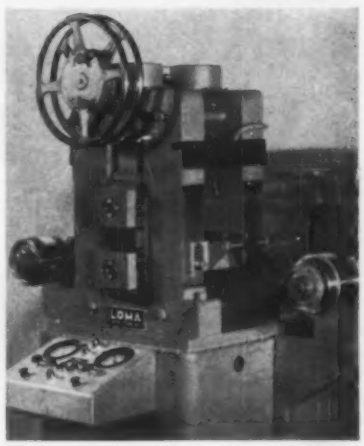
An editor's activities include many things in addition to editing, writing and processing papers. For example, Assistant Editor Ralph Dermott (shown, standing, in the photo right) served as a judge in the New Jersey Zinc Co.'s "Die Casting of the Year" contest (along with J. H. Schaum, editor, *Modern Castings*, and Norman E. Kewley of General Electric Co.). The contest, which carries a $1000 grand prize, was started this year "to recognize the unsung talents of the die casting engineer". The winning entry and some of the other outstanding die casting applications are described on p. 122.

Editor Allen Gray (below, right), acting as chairman of the 1960 Design Contest sponsored by the Gray Iron Founders' Society, helped pick the winner of yet another contest. It was a tough job to pick the winner of the $500 first prize from the more than 50 new casting designs entered in the contest but even the losers fared well – each entrant was given a $10 Gray Iron Castings Handbook described as "the only complete reference manual in the country on gray and ductile iron castings". In presenting the award, Editor Gray noted that "at no time during the past ten-year history of this award has design innovation, material selection and processing been so important to all manufacturers of metal products because of the need to use improved technology to offset the profit squeeze".

This December issue, with its bright red "cross" on the cover, is our way of wishing you a Merry Christmas. Our New Year greeting will be the January issue. In addition to its report on international progress in metallurgy, this first issue of 1961 will contain a concise report for technical management forecasting what can be expected in metal technology in the months ahead. THE EDITORS

NEWS FROM

LOMA



This rugged and versatile reversing 2-high / 4-high combination mill brings high-precision rolling of thin-gauge ferrous and non-ferrous strip within reach of the smaller re-rolling mill, metals pilot plant and research laboratory. Occupying only 35 sq. ft. of floor space and involving a cost of less than $20,000, the machine handles up to 6 in. wide strip at rolling speeds up to 250 ft. per min. with accurate front and back tension control.

The new 8 in. mill is furnished with two sizes of 4-high work rolls, made of either alloy tool steel or solid tungsten carbide: the 1½ in. size is used for normal cold reduction down to 0.002 in. thickness, and the ¾ in. size allows special ultra-thin finishing to gauges of less than 0.001 in. In the 4-high setup, the machine handles up to ⅛ in. gauge; the 2-high arrangement is used for the hot or cold breakdown of heavier materials up to 1 in. thick, but is also available for skin pass rolling of thin strip.

The production of close-tolerance stock is assured by an exceptionally rugged mill design, employing steel housings of 160 sq. in. post area, super-precision needle roller journal bearings of 175,000 lb. separating force capacity, a heavy-duty mill drive with herringbone gearing and universal joint spindles, and twin-handwheel worm drive screwdowns. The machine is powered by a four-speed reversing drive offering constant horsepower from 40 to 250 ft. per min. rolling speed.

The outstanding feature of the new machine is its reversing strip coiling attachment allowing the two-way rolling of strip under tension control with no more effort than a mere flick of a selector switch. Mounted on brackets at either side of the mill, the two coiling shafts carry 8 in. diameter reels designed for a coil buildup of 6 in. Both shafts are driven from the pinion stand and are provided with dual air-operated slip clutches and brakes of ultra-sensitive, low-inertia design. Selective operation through solenoid valves and pressure regulators precisely controls the front and back tensions desired for any given mill pass.

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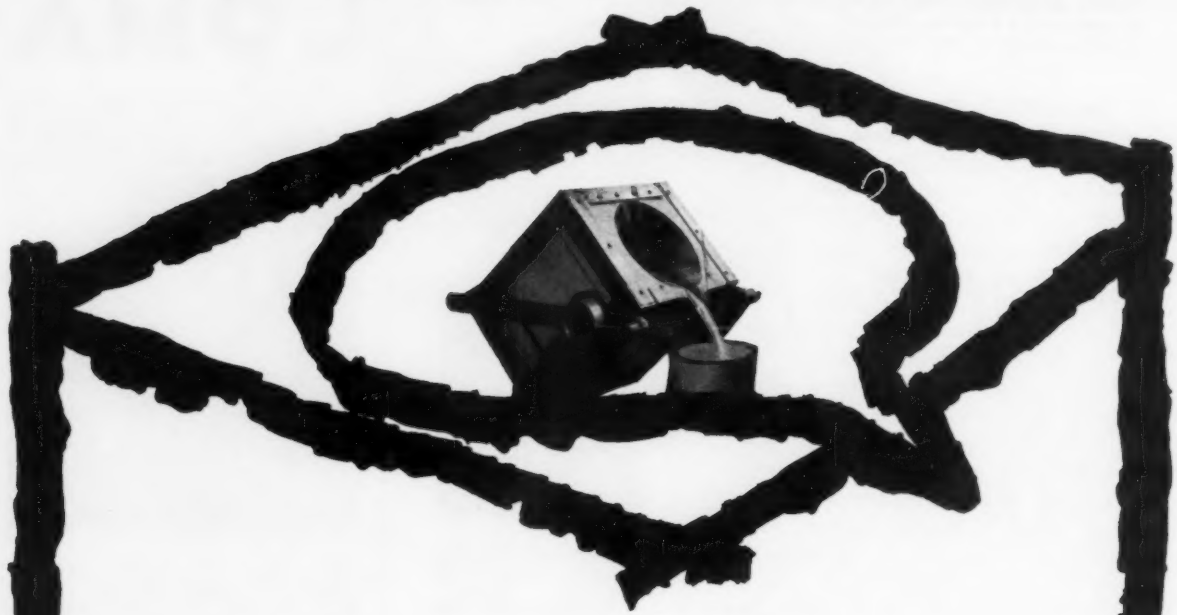
WHY BIG THINGS ARE HAPPENING IN INDUCTION MELTING



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If you'd like more information on Inductotherm furnaces, write for Bulletin 70. But, for a taste of Inductotherm service, ask to have an engineer call. Inductotherm Corporation, 412 Illinois Avenue, Delanco, New Jersey.

INDUCTOTHERM

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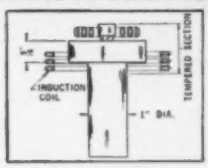
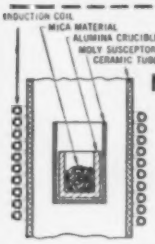
TYPICAL INDUCTION HEATING APPLICATIONS



Punch Heads Selectively Tempered

Diagram shows arrangement for selectively tempering heads of alloy steel punches. The use of a combination type solenoid and pancake induction coil reduces hardness from Rc 55/56 to Rc 41/44, improving resistance to brittle fracture at the head of the punch. In this case a heating cycle of 55 seconds provides uniform tempering. A multiple position fixture, processing 4 pieces at one time, speeds up production.



Heating Non-Conducting Materials To High Temperatures

Laboratory analyses frequently require heating of non-conducting materials to temperatures of 3,000 to 3,500° F. in vacuum or special atmosphere. This can be accomplished by induction heating with the aid of a metal susceptor. Diagram shows the fusion of mica samples in an alumina crucible, using molybdenum susceptor. A ceramic tube surrounding the susceptor isolates the work for fusion in a vacuum. The molybdenum susceptor is heated by induction, which in turn, heats the crucible by radiation.

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HANDY ALLOY DATA SHEET

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	Ag	Cu	Zn	Other	°F	°C	°F	°C	
EASY-FLO	50	15½	16½	(18 Cd)	1160	625	1175	635	5.0
EASY-FLO 3	50	15½	15½	(16 Cd-3 Ni)	1170	630	1270	690	5.0
EASY-FLO 45	45	15	16	(24 Cd)	1125	605	1145	620	4.9
EASY-FLO 35	35	26	21	(18 Cd)	1125	605	1295	700	4.9
SIL-FOS	15	80		(5 P)	1185	640	1300	705	4.5
SIL-FOS 5	5	88¾		(6¼ P)	1185	640	1300	705	4.4
TEC*	5			(95 Cd)	640	340	740	395	4.6
TEC-Z*	5		16.6	(78.4 Cd)	480	250	600	315	4.5
BRAZE 071 (SN #7)†	7	85		(8 Sn)	1225	665	1805	985	4.8
" TL	9	53	38		1410	765	1565	850	4.5
" ATT	20	45	30	(5 Cd)	1140	615	1500	815	4.6
" 202 (AT SPEC)†	20	45	35		1315	715	1500	815	4.7
" NE	25	52½	22½		1250	675	1575	855	4.7
" 251 (AE)†	25	57½	17½		1270	690	1625	885	4.7
" NT	30	38	32		1250	675	1410	765	4.7
" DT	40	36	24		1235	670	1415	770	4.8
" SS	40	30	28	(2 Ni)	1220	660	1435	780	4.8
" 404 (SS-5)†	40	30	25	(5 Ni)	1220	660	1580	860	4.7
" DE	45	30	25		1225	665	1370	745	4.8
" ETX	50	34	16		1250	675	1425	775	5.0
" 541 (4772)†	54	40	5	(1 Ni)	1340	725	1575	855	5.1
" 560 (ER)†	56	22	17	(5 Sn)	1145	620	1205	650	5.0
" 580 (EB)†	57½	32½		(7 Sn-3 Mn)	1120	605	1345	730	5.1
" RT	60	25	15		1245	675	1325	720	5.0
" 603 (RT-SN)†	60	30		(10 Sn)	1115	600	1325	720	5.2
" 630 (RSNI)†	63	28½		(6 Sn-2½ Ni)	1275	690	1475	800	5.1
" EASY	65	20	15		1240	670	1325	720	5.1
" 655 (RE-MN)†	65	28		(5 Mn-2 Ni)	1385	750	1560	850	5.2
" MEDIUM	70	20	10		1275	690	1360	740	5.1
" BT	72	28			1435	780	1435	780	5.2
" HARD	75	22	3		1365	740	1450	790	5.3
" 752 (TR #1)†	75		25		1300	705	1330	720	5.1
" IT	80	16	4		1340	725	1490	810	5.3
" 852 (85 Ag-15 Mn)†	85			(15 Mn)	1760	960	1780	970	5.1
PREMABRAZE 610	61	24		(15 In)	1155	625	1305	705	5.0

*A Solder – Not a Brazing Alloy. †Former Names

Space does not permit listing the many special alloys, formulated for a particular or unique application. Handy & Harman Brazing Engineers and Technical Service are always ready to work closely with you on metal joining problems and methods.

Comprehensive technical literature covering all aspects of brazing methods and alloys awaits your request.

GET THE FACTS FROM BULLETIN 20

This informative booklet gives a good picture of silver brazing and its benefits...includes details on alloys, heating methods, joint design and production techniques. Write for your copy.

Your No. 1 Source of Supply and Authority on Brazing Alloys

HANDY & HARMAN

General Offices: 82 Fulton St., New York 38, N. Y.

Offices and Plants: Bridgeport, Conn. • Chicago, Ill. • Cleveland, Ohio • Dallas, Texas • Detroit, Mich.
Los Angeles, Calif. • New York, N. Y. • Providence, R. I. • San Francisco, Calif. • Montreal, Canada • Toronto, Canada

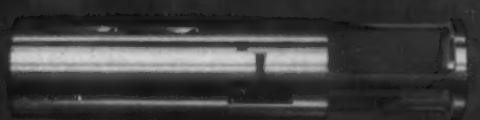
DISTRIBUTORS IN PRINCIPAL CITIES

Circle 2456 on Page 48-8

you can blank it...

you can forge it...

you can polish it...



but you can never, no never, change its **consistent uniformity!**

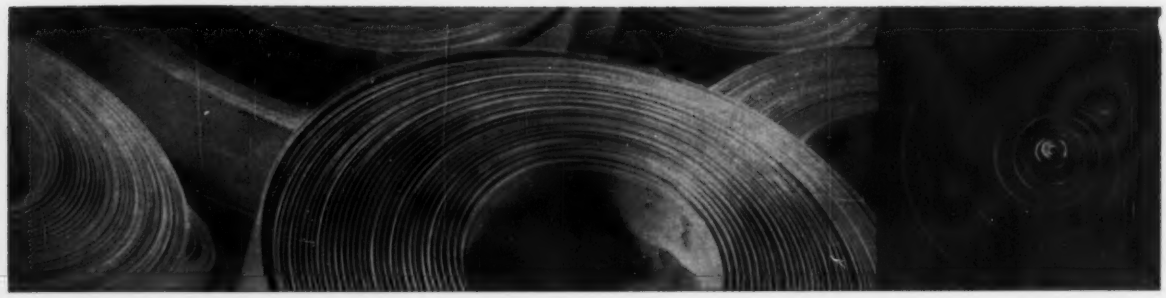
...and that means maximum production, accurate conformity to specifications, fewer rejects and increased profits with **Carpenter Specialty Stainless** ...produced by one of the leaders of stainless steels for industry.

Carpenter steel

you can do it ***consistently*** better with Carpenter Stainless Steels for specialists

Circle 2457 on Page 48-B

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
Alloy Tube Division, Union, N. J.
Webb Wire Division, New Brunswick, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.



Check your requirements against these

Wallace Barnes Cold-rolled Specialty Steels

Furnished in these carbon grades:

1.25 – 1.32% .90 – 1.05% .70 – .80% .59 – .74% .48 – .55%

ANNEALED AND HARD-ROLLED

Thickness

.003 – .010″	in widths	1/8	to 6 1/4″
.011 – .014″	“ “	3/16	to 11″
.015 – .019″	“ “	3/16	to 13″
.020 – .035″	“ “	1/4	to 13″
.036 – .049″	in widths	3/8	to 13″
.050 – .064″	“ “	1/2	to 13″
.065 – .093″	“ “	3/4	to 6 1/4″
.093 – .125″	“ “	3/4	to 6 1/4″

HARDENED AND TEMPERED

Scale-free or scaleless; polished*; polished and blued*; polished and strawed*

Thickness

.003 – .004″	in widths	1/8	to 2″
.005 – .007″	“ “	1/8	to 3″
.008 – .009″	“ “	1/8	to 4″
.010 – .014″	“ “	3/16	to 5″
.015 – .019″	“ “	3/16	to 7″
.020 – .025″	“ “	1/4	to 8 1/2″
.026 – .030″	“ “	1/4	to 8″
.031 – .035″	in widths	1/4	to 7″
.036 – .040″	“ “	3/8	to 7″
.041 – .049″	“ “	3/8	to 6″
.050 – .060″	“ “	1/2	to 4″
.061 – .064″	“ “	1/2	to 3″
.065 – .093″	“ “	3/4	to 3″

*Maximum width for polishing in .010 – .030 thickness ranges is 5 in.

Facilities for processing alloy steels also are available.

Standard sizes normally available for prompt shipments.

Write for a copy of “Physical Property Charts” that give performance characteristics of .90 – 1.05% and .70 – .80% carbon grades.

Wallace Barnes Steel Division

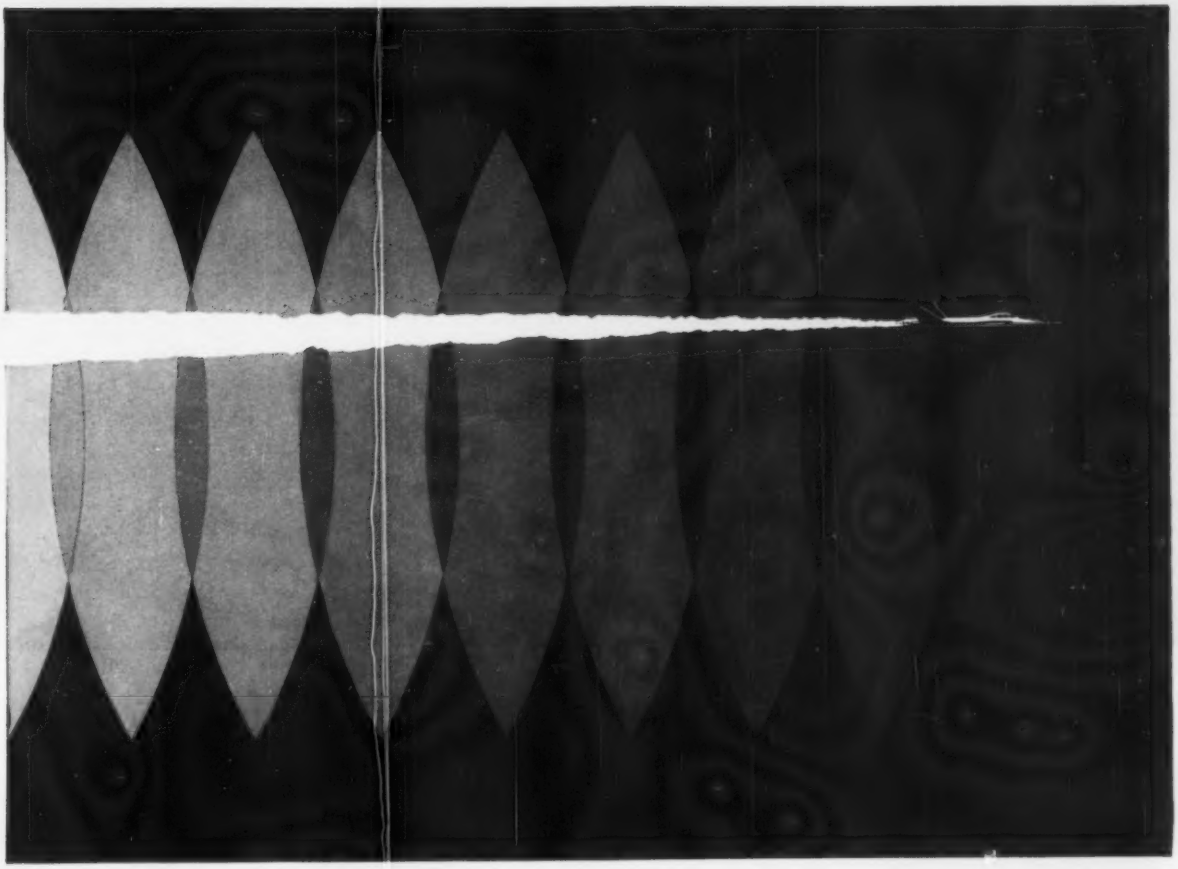
Bristol, Connecticut

Associated Spring Corporation

8818

Circle 2453 on Page 48-8

Metallurgical Memo from General Electric



How a super alloy will hit Mach 3 from a vacuum start

Metallurgical Products Department reports on
René 41*—and on how its unique properties make it ideal
for use in everything from jets to machine components

When machine-component specifications call for the "impossible"—top strength combined with high temperature resistance and minimum weight—a vacuum-induction-melted alloy may be the answer.

René 41—General Electric's super alloy—finds wide application in machine design as well as in jet engine components. Virtually free from impurities, René 41 can be successfully forged, welded, or formed; offers top tensile and stress rupture strengths, increased ductility. All this with minimum weight—a combination found in no other alloy!

Got a design problem? Choose from General Electric's variety of high-purity, vacuum-induction-melted alloys in sheets, bars, billets, wire, or castings. For detailed information—or the assistance of one of our engineers—write today to: *Metallurgical Products Department of General Electric Company, 11113 E. 8 Mile Street, Detroit 32, Michigan.*

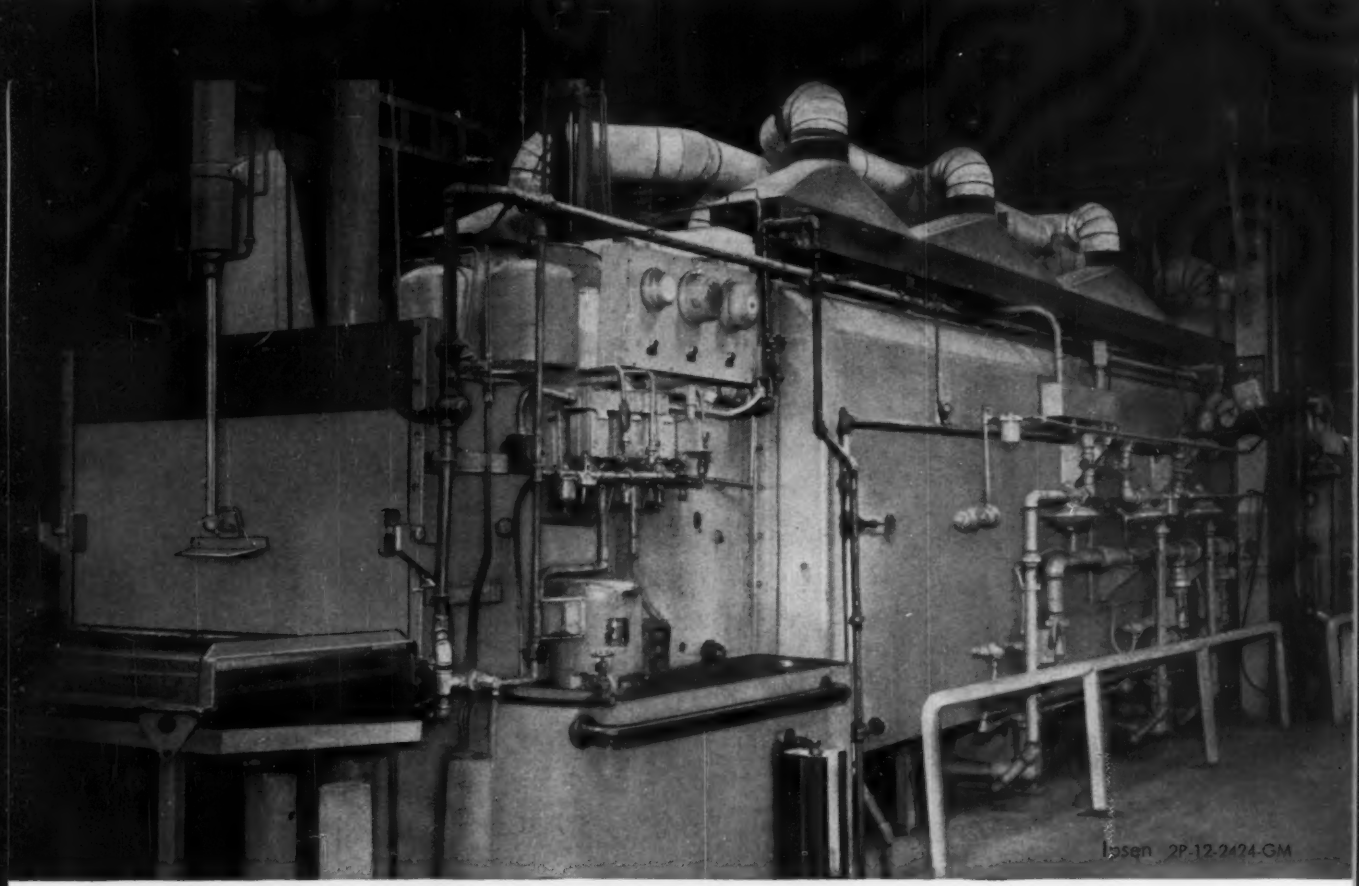
**René 41 is a trademark of the General Electric Company*

METALLURGICAL PRODUCTS DEPARTMENT

GENERAL ELECTRIC

CARBOLOY® CEMENTED CARBIDES • MAN-MADE DIAMONDS • MAGNETIC MATERIALS • THERMISTORS • THYRITE® • VACUUM-MELTED ALLOYS

Circle 2459 on Page 48-B



Production Carburizing

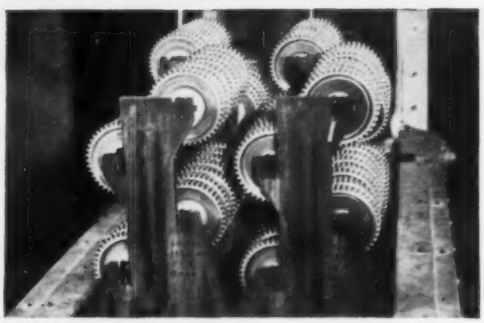
Five years ago the first Ipsen Double Row 4-Zone Pusher was built..see photo above. It is now six years since the first Deep Case Carburizing Unit was built. BIG Ipsen controlled atmosphere pushers have given unexcelled metallurgical results!

Check these features when you consider a carburizing furnace. They are exclusive with Ipsen.

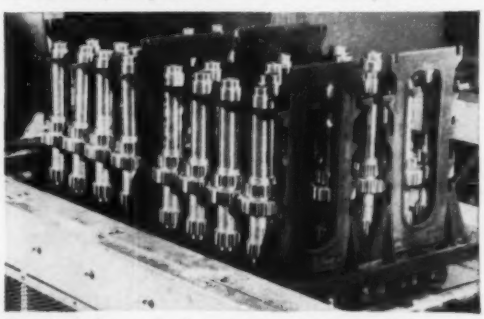
- Enclosed Charging Mechanism (Pat. No. 2,896,775)
- Chain Discharging Mechanism (Pat. No. 2,842,349)
- Baffles for 100% Forced Convection Heating (Pat. No. 2,788,205)
- Ceramic Heating Tube Mounting (Pat. No. 2,822,798)
- Ceramic "Flame-Busters" (Pat. No. 2,861,596)
- Ceramic Fan (Pat. No. 2,730,352)
- Water-Cooled Fan Motor (Pat. No. 2,800,317)
- Quench Oil Flow System (Pat. No. 2,854,013)

Other Patents Pending

Ipsen Pusher furnaces are described in Bulletin P-59. Send for your copy today.



This charge of steel gears is typical of work handled in Ipsen Production Carburizing Furnaces. Heating was 1700° F for 10 hours; oil quenched at 150° F. Case depth: .045".



Countershafts ready for charging into Ipsen Production Carburizing Furnace. Heating time was 10 hours at 1700° F; quenching was in oil at 150° F. Case depth: .045".

AUTOMATIC Ipsen HEAT TREATING UNITS

IPSEN INDUSTRIES, INC. • DEPT. 23 • P. O. BOX 500 • ROCKFORD, ILLINOIS

Circle 2460 on Page 48-B

CUSTOM-MADE

Stainless Strip from Allegheny Ludlum

Stainless steel strip problems are solved at Allegheny Ludlum. Excellent forming characteristics, close gauge control, special analyses, color matching, and special finishes are only a few of the plusses A-L offers to solve your problems.

Here are some examples of A-L stainless strip made to solve individual problems:

- Type 430 with low roping quality.
- The economical 200 series . . . line free! And with increased ductility.
- Type 430 with a bright mirror finish, free of gray streaks.
- Type 302 with quality that enables a fabricator to form a coffee percolator in nine draws without an intervening anneal.

Your individual needs will get the attention you want them to have at Allegheny Ludlum. Tell your A-L representative the end use, fabrication procedures, etc., for your strip. He will work with A-L metallurgists, processing engineers, and technical men to give you the best stainless strip, custom made for your use.

Allegheny Ludlum service in stainless strip is backed up by an outstanding record for on-time delivery. Large stocks of hot bands enable A-L to give you quick service on all stainless strip needs. And A-L finished stocks give you quick, even overnight, delivery on many gauges and analyses.

For consistent temper, tolerances, and finish in stainless steel strip, call your Allegheny Ludlum salesman, or write: Allegheny Ludlum Steel Corp., Oliver Bldg., Pittsburgh 22, Pennsylvania. Address Department MP-12.

3374

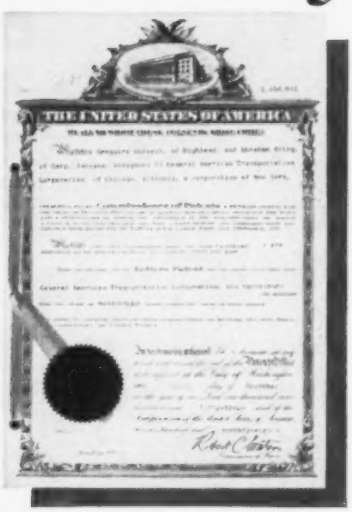
ALLEGHENY LUDLUM

EVERY FORM OF STAINLESS . . . EVERY HELP IN USING IT

Circle 2461 on Page 48-B

a Reminder

to those who use chemical nickel alloy plating:



There is only ONE

Kanigen®

and 29 patents prove it

There are no substitutes for Kanigen—no other process that applies a hard, corrosion-resistant nickel alloy coating without the use of electricity as Kanigen does.

With Kanigen, you can plate anything from a small relief valve to a 20,000 gallon tank car with a virtually non-porous, uniform coating.

How can you be sure of getting Kanigen? Only one way—by calling General American or one of its licensees. For further information write:

Kanigen Division
GENERAL AMERICAN TRANSPORTATION CORPORATION
135 South LaSalle Street
Chicago 3, Illinois
Offices in principal cities

KANIGEN GENERAL AMERICAN

LICENSEES

INDUSTRIAL KANIGEN CORPORATION
1421 Park Avenue
Emeryville, California

KEYSTONE CHROMIUM CORPORATION
1095 Niagara Street
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KEYSTONE METAL FINISHERS, INC.
22 Raydol Avenue
Secaucus, New Jersey

Circle 2462 on Page 48-E

for High Temperature Tooling—
ENGINEERING DESIGNS give Better Service!
The designs illustrated are typical examples of those supplied to our customers every day. Such design studies—specifically ENGINEERED for each application—not only help visualize mechanical features of individual jobs, but also illustrate the many alloy design details incorporated for better serviceability.
The unique experience of our staff is reflected in our designs. We of course consider efficient loading, convenient handling, and functional operation with furnace mechanisms. Of equal importance to serviceability is the ENGINEERING evaluation of the complex stresses and deformations encountered in use at high temperatures, and in quenching. Atmosphere and quench circulation in critical part areas are given special attention.
An equal caliber of ENGINEERING is employed in our product manufacture—where our proprietary processes have received both national and international recognition.

HEAT RESISTANT CASTINGS
ACCOLOY
STAINLESS STEEL CASTINGS

Remember—this unparalleled comprehensive ENGINEERING service is available to our customers without charge.

ALLOY ENGINEERING & CASTING CO.

1700 W. WASHINGTON ST., CHAMPAIGN, ILL. TELEPHONE FLEETWOOD 6-2568

ENGINEERS AND PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

Quality Steel

BETTER STEEL in ever-increasing quantities and varieties is needed by the world's growing industries.

YAWATA, biggest steelmaker in the Far East, has achieved its pre-eminence by concentrating on quality, dependability and low-cost production.

For your specific needs in STEEL, small or big, contact YAWATA for assured satisfaction.

Circle 2464 on Page 48-B

YAWATA IRON & STEEL CO., LTD.

Head Office: No. 1, 1-chome, Marunouchi, Chiyoda-ku, Tokyo, Japan
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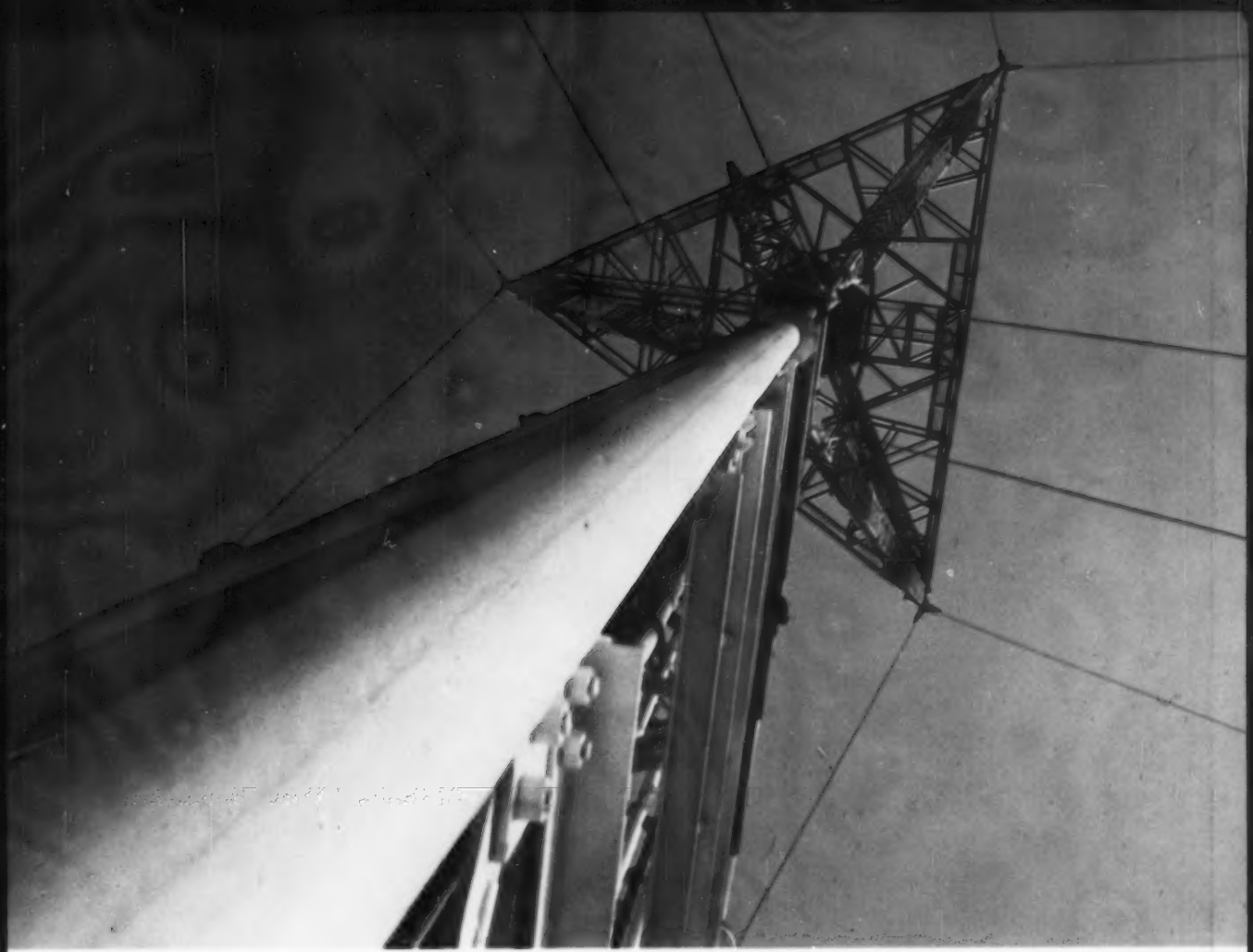


USS "T-1" Steel cuts size of tower legs 50%

This spectacular, 730-foot, candelabra-type TV tower in Baltimore, Maryland, was built to withstand hurricane winds of 165 mph. The legs had to be *extra* strong to support the weight of three 10-ton antennas plus the weight of a triangular platform 105 feet long on each side.

The designers chose USS "T-1" Constructional Alloy Steel for the legs because its great strength permitted a reduction in leg size of almost 50%. Wind resistance was reduced and only 105 tons of 5¾" to 7" quenched and tempered, straightened and stress-relieved "T-1" Steel rounds were used for the legs. If structural carbon steel had been used, approximately 300 tons of steel in diameters up to about 12 inches would have been necessary.

Chief advantages of USS "T-1" Steel

You may not be in the market for a TV tower, but if you are building large structures or rugged equipment, "T-1" Steel offers these plus values:

Super Strength—Minimum yield strength 100,000 psi in bar diameters up to 4 inches or plate thicknesses up to 2½"—three times the yield point of structural carbon steel.

World's first 3-antenna, candelabra-type TV tower for Baltimore stations WBAL, WJZ and WMAR. Designed and fabricated by Dresser-Ideco Co., Columbus Ohio. Erected by J. F. Beasley Construction Co., Muskogee, Okla.

Resistance to impact abrasion—Very high. Shovel parts, truck liners, conveyor parts, bins, chutes last up to five times as long.

Atmospheric Corrosion Resistance—Four times that of carbon steel. This results in a considerable increase in paint life.

Toughness—Outstanding at both low and high temperatures.

Weldability—Readily weldable without preheating or stress relieving.

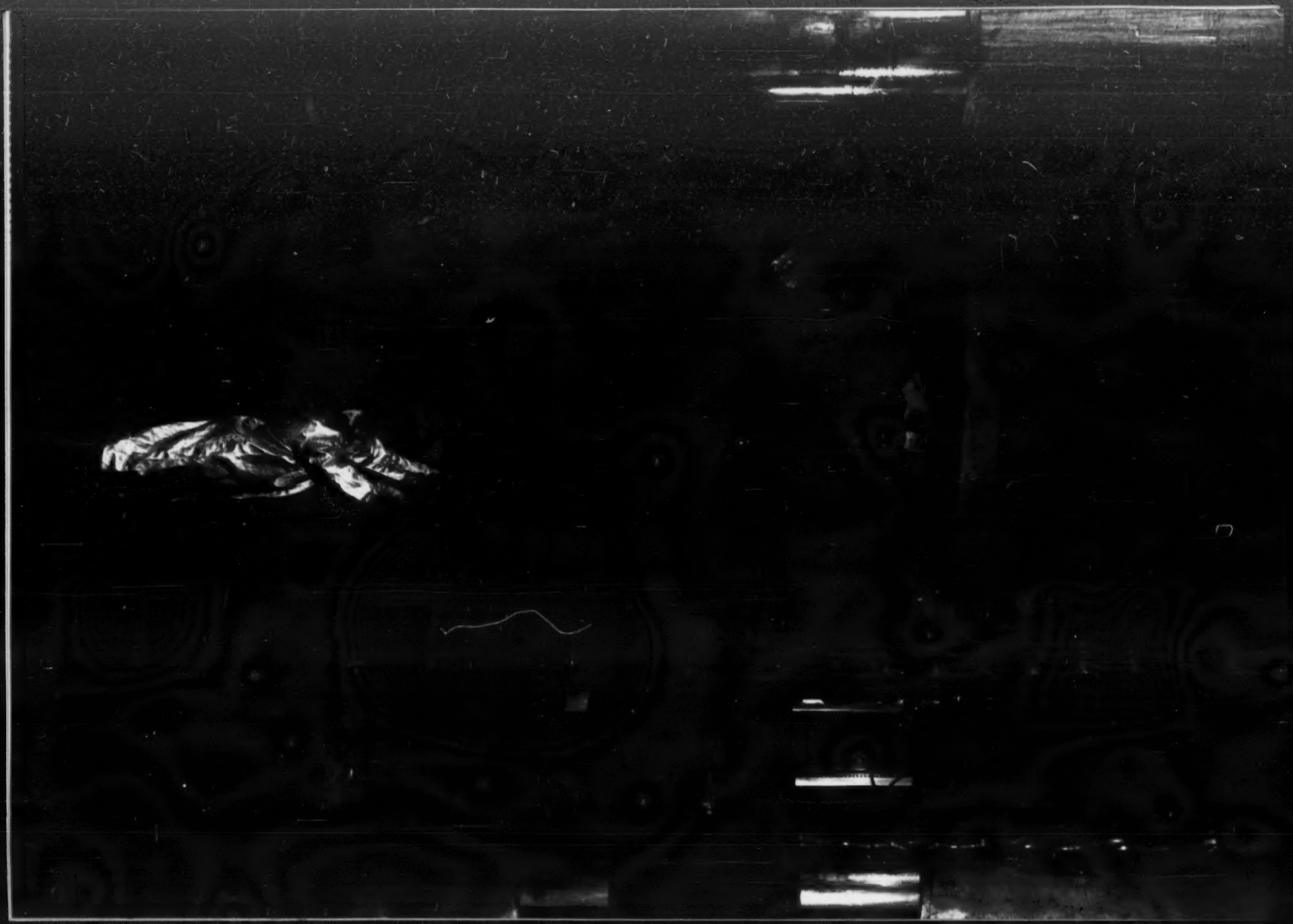
Costs—Where the designer takes full advantage of "T-1" Steel's superior properties, overall costs can be greatly reduced due to sizable savings possible in material, fabrication, construction and maintenance.

Write for our book, "USS 'T-1' Steel," which gives complete information. United States Steel, 525 William Penn Place, Pittsburgh 30, Pa.

USS and "T-1" are registered trademarks

United States Steel Corporation—Pittsburgh
Columbia-Geneva Steel—San Francisco
Tennessee Coal & Iron—Fairfield, Alabama
United States Steel Supply—Steel Service Centers
United States Steel Export Company

United States Steel



This mark tells you a product is made of modern, dependable Steel.

New top for the Shippingport reactor

By the Ohio River at Shippingport, Pa., the United States' first full-scale central station atomic power plant devoted exclusively to civilian needs continues to generate electricity for the Pittsburgh district. In operation since 1957, Shippingport's reactor core received its second "seed" fuel early this year. The pioneer atomic plant is a joint project of the Duquesne Light Company and the Atomic Energy Commission.

The nuclear portion of Shippingport was designed and developed by Westinghouse under the direction of and in technical cooperation with the Naval Reactors Branch of the Atomic Energy Commission. The work was done at the Bettis Atomic Power Laboratory which Westinghouse operates for the AEC.

U. S. Steel's Homestead Plant is supplying the forgings for the closure-head assembly needed to accommodate a new and higher power core being developed by the Bettis Laboratory for Shippingport. As furnished, the 3-piece assembly weighs 81 tons—and every ounce of these USS Quality Forgings have been cast, forged, machined and tested to meet the most rigid specifications.

The reactor's new closure-head assembly for Core 2 consists of a dome, torus, and head flange. The largest piece—the head flange—weighs 41 tons. To insure the highest degree of quality from the start, it was electric-furnace melted from a Ni-Cr-Mo alloy steel, then teemed into a 180-ton ingot in U. S. Steel's vacuum-casting facilities. After top and bottom discard, it was forged to an 85″ octagon; then it was upset to 60″ in height. Next a 30″ hole was punched in it to provide for mandrel forging. This hole was later opened up to take a 36″, and finally a 54″ forging bar. At this point the ring was flattened to 43″, the bar was again inserted in the center and the ring was mandrel-forged to its final dimensions—159″ overall diameter, 98″ interior diameter, and 42½″ high, as shown in the big picture. It then weighed 83½ tons and was ready for heat treating and preliminary machining. Final machining reduced the flange's shipping weight to 41 tons.

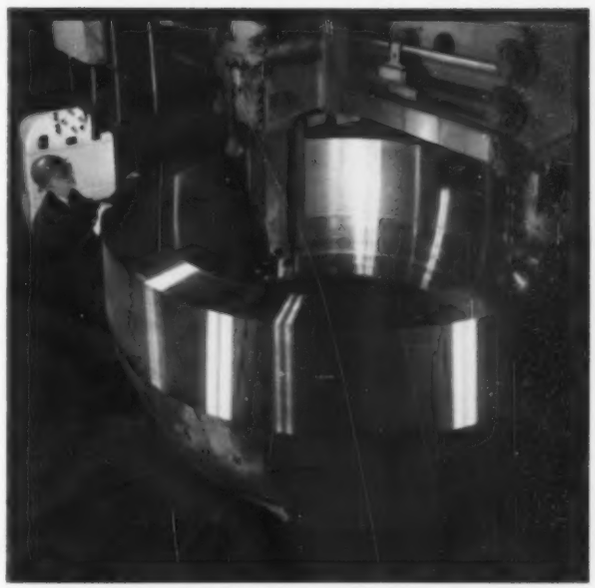
The torus, or "transition ring," was manufactured from the same grade of steel in the same careful, expert manner. It weighs 23 tons after final machining.

The dome is hollowed out on the inside and has a relatively small hole through its middle. This hole will provide a refueling port; separate openings for control rod mechanisms will be bored later. The dome was machined on our 20′ vertical boring mill with the aid of an electronic contouring machine. Final weight of the dome: 17 tons.

Dome, torus and flange were painstakingly tested and inspected every step of the way. Tests included ultrasonic inspection, tangential tension tests, Charpy V notch impact tests, grain size tests, bend tests and magnetic particle inspection.

U. S. Steel has the capacity, the men, and the equipment to manufacture quality forgings like these, whether they be rings, flanges, domes, pressurizers, tube sheets or other such nuclear and power plant components. And the very same men and equipment will be working on *your* order. For a free folder on USS Nuclear Forgings, write United States Steel, 525 William Penn Place, Pittsburgh 30, Pennsylvania.

USS is a registered trademark



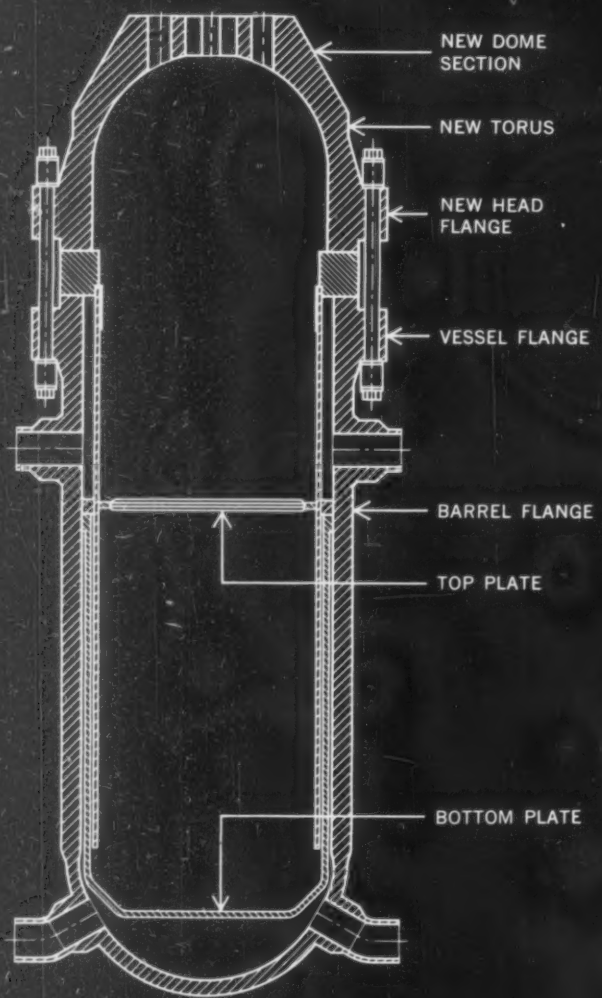
Photos, top to bottom—
head flange about to be quenched;
torus being contour machined;
ultrasonic inspection of dome.

United States Steel Corporation—Pittsburgh
Columbia-Geneva Steel—San Francisco
Tennessee Coal & Iron—Fairfield, Alabama
United States Steel Export Company

United States Steel

Core 2

FORGED COMPONENTS



Since the three parts of this reactor vessel head—dome, torus and flange—will be welded into a single unit, there can be no allowance for failure. Every square inch of these three USS Quality Forgings were painstakingly manufactured and carefully inspected during and after the manufacturing process to assure perfection. The men, the forging facilities and the inspection equipment are available to you if you need forgings that must be as close to perfection as we can make them.

USS "T-1" Steel saves 289 tons of weight in 16 lo

This is a story about how the tremendous strength of USS "T-1" Steel was utilized to save 289 tons of weight in the lock gates at the new Greenup, Kentucky and Markland, Indiana locks and dams on the Ohio River. Each lock gate has five diagonal braces that were designed for USS "T-1" Constructional Alloy Steel. At Greenup, it was estimated that 64 tons of "T-1" Steel did the work of 213 tons of carbon steel in eight gates. At Markland, 60 tons of "T-1" Steel were used instead of 200 tons of carbon steel to do the same job.

The diagonal units provide the supports which are absolutely essential to brace the gates. Each diagonal is a flat bar 8 inches wide by 1½ inches thick and about 73 feet long and weighs around 3,200 pounds. Toward the center of the diagonal is a turnbuckle used to adjust tension. By using USS "T-1" Steel, which has a minimum yield strength of 100,000 psi, both the size and weight of the diagonals were greatly reduced while retaining an ample factor of safety.

Lower costs. Reduction in weight because of the use of USS "T-1" Steel meant lower overall material costs, reduced shipping costs by more than one third, and decreased handling and erection costs.

USS "T-1" Steel for hoists. Four hoists for the emergency gates at Greenup locks and c
USS "T-1" Steel by McNally Pitts
burg, Kansas. The structures are gi
feet long and 41 inches deep. Flanges
2½ inches thick. The webs are 36 inc
thick. All were fabricated from "T
girder weighs about 12,000 pounds.

The new locks and dam on the O
Kentucky were built under supervisio
District, U. S. Army Corps of Engi
locks at Markland, Indiana was bui
District, U. S. Army Corps of Enginee
Nashville Bridge Company.

Other uses of USS "T-1" St
Wherever great strength is needed v
as in bridges, TV towers, pressure ves
penstocks, USS "T-1" Steel offers ma
big construction machinery, "T-1" S
cause of its strength, high resistance t
weldability. For complete informatio
book. United States Steel, 525 Willi
burgh 30, Pa. *USS and "*

This mark tells you a product is made of modern, dependable Steel.

United States Steel Corporatio
Columbia-Geneva Steel –
National Tub
Tennessee Coal & Iron – Fair
United States Steel Supply – Steel S
United States Steel Ex

United S

lock gates

and dam were also built of
Pittsburg Mfg. Co., Pitts-
re girder sections about 25
anges are 20 inches wide by
6 inches deep by 1¼ inches
"T-1" Steel plates. Each
ds.
he Ohio River at Greenup,
vision of Huntington, W. Va.
Engineers. A similar set of
s built under the Louisville
gineers. Gates fabricated by

" Steel in construction.
ded with least weight, such
re vessels, and high pressure
s many advantages. And for
1" Steel is unsurpassed be-
nce to impact abrasion, and
nat'on, write for our "T-1"
William Penn Place, Pitts-

and "T-1" are registered trademarks

poration – Pittsburgh
Steel – San Francisco
nal Tube – Pittsburgh
n – Fairfield, Alabama
Steel Service Centers
Steel Export Company
ted States Steel

USS

Bright solution for a bright annealing problem

The non-magnetic stainless steel parts above are used by Waterman Products Company, Philadelphia, Pa., in electron tubes. They are bright annealed at 1150 C (2102 F) maximum temperature in a dry hydrogen atmosphere on a 15 minute cycle. The furnace employs an Inconel muffle, water cooled at the rear for quick cooling of the work.

Since close, uniform temperature control and utmost cleanliness are necessary, electric heat offers obvious advantages. Ordinary ribbon elements, however, have a working limit of about 1150 C (2102 F)—too close to the maximum temperature used for practical operation.

What's the answer? The Waterman Products Company solves the problem by having the parts annealed in a 40 kilowatt electric furnace designed and built by the Drever Company, Bethayres, Pa., equipped with GLOBAR® silicon carbide heating elements.

GLOBAR elements can be used with safety to above 1510 C (2750 F). There are no combustion products to cause problems. There are no stack losses, and radiation loss is reduced to a minimum through the use of insulating refractories. The result is greater efficiency and a cooler shop. GLOBAR elements, moreover, make possible a simpler, more compact furnace, saving space and expense.

The advantages of heating with GLOBAR elements often more than cancel out differentials in Btu costs between electricity and other fuels. Why not investigate with your furnace builder—or write to Refractories Division, Globar Plant, Dept. MP-120, The Carborundum Co., Niagara Falls, N. Y.

For latest advances in silicon carbide heating elements... count on

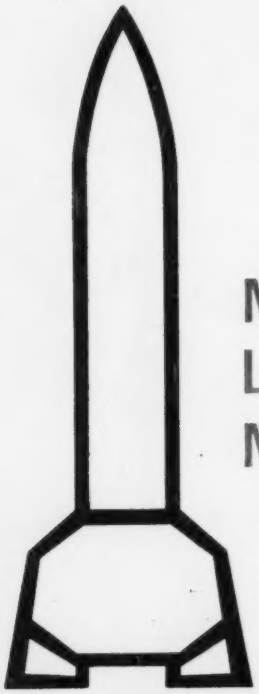
CARBORUNDUM®

Circle 2421 on Page 48-B

For precise, economical electric heating

GLOBAR silicon carbide heating elements

- Shipped from stock or within two weeks.
- Temperatures from 1400 to 2800 F, precisely controlled, independent of atmosphere.
- Easily replaced from outside without waiting for furnace to cool.
- "On line" operation for many applications—no transformer necessary.
- Elements 4" to 105" in length.
- For greater economy in heat treating, brazing, forging, melting, and sintering.



MISSILE LAUNCHER MADE MOBILE-LIGHT, TAKEOFF-TOUGH WITH

N-A-XTRA

HIGH-STRENGTH STEEL

A battlefield might be anywhere. Wherever it is, there may be a need for the new 10,000-pound, 36-foot Sperry-Rand U.S. Army Sergeant missile. That's why the launching station on which the missile is assembled, aimed and fired must be light enough to be transported by land, sea or air. Yet it also has to be rugged and strong enough to assure the launcher's availability for subsequent firing.

N-A-XTRA steels meet all the conditions of light weight, high strength and impact resistance. Pound for pound, they're nearly three times stronger than mild carbon steel. They are used, not only in this mobile missile launcher, but in many other defense products and in commercial equipment such as earth-moving vehicles, heavy machinery and pressure vessels.

Fabrication qualities are an N-A-XTRA bonus. Even at extreme subnormal temperatures, they remain tough and readily weldable. Conventional methods—cold forming, gas cutting, shearing and machining—give superior results, too. For further information, write Product Development Department, Great Lakes Steel Corporation, Detroit 29, Michigan.

N-A-XTRA

A PRODUCT OF

GREAT LAKES STEEL

Detroit 29, Michigan

Quenched and tempered N-A-XTRA, *the best low carbon extra-strength alloy steels you can buy, are available in four levels of minimum yield strength, from 80,000 to 110,000 psi. They are tough at normal and subnormal temperatures and can be readily and reliably welded. Sizes range from ⅛" to 1" thick, up to 72" wide and up to 35' long.*

Steel

Look for the STEELMARK on the products you buy; place it on the products you sell.

Great Lakes Steel is a Division of **NATIONAL STEEL CORPORATION**

NOW TESTING AT 4000°F

complete high temperature instrumentation by **RIEHLE** *"Warms Up" to new research challenges*

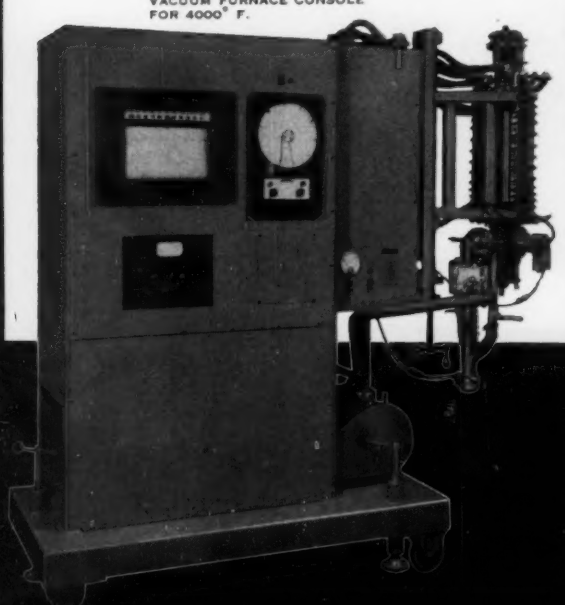
CREEP AND STRESS RUPTURE TESTING MACHINES

HYDRAULIC FATIGUE TESTING MACHINES

HYDRAULIC UNIVERSAL TESTING MACHINES

UNIVERSAL SCREW POWER TESTING MACHINES

TYPICAL ARRANGEMENT OF RIEHLE HIGH TEMPERATURE VACUUM FURNACE CONSOLE FOR 4000° F.



As elevated temperature ranges climb, RIEHLE TESTING MACHINES keep pace by building COMPLETE systems of equipment capable of testing physical properties of materials at high temperatures.

RIEHLE offers you ready-to-operate systems incorporating all of these components:

1. **BASIC TESTING MACHINE**
2. **STRAIN MEASURING INSTRUMENTATION** for atmosphere, controlled atmosphere furnaces and vacuum furnaces.
3. **COMPLETE HIGH TEMPERATURE ACCESSORIES** including furnaces, temperature controllers, vacuum pumps, extensometers and complete related instrumentation.

You can rely on RIEHLE for complete strain measuring instrumentation from room temperature snap-on extensometers to dual range instruments and highly sophisticated vacuum furnace extensometers for temperatures up to 4000° F.

Save time on vital projects by contacting RIEHLE now about your requirements for physical testing at elevated temperatures. Write Dept. MP-1260.

Circle 2423 on Page 48-B

Riehle® TESTING MACHINES

A DIVISION OF

American Machine and Metals, Inc.

EAST MOLINE, ILLINOIS

NEW PRODUCTS

Nonferrous Metals

Aluminum Screw Machine Stock

An Al-Mg-Si alloy containing lead and bismuth, 6262-T9, offers superior strength and improved machinability compared to other standard free-machining alloys, and the corrosion resistance is not impaired. Typical properties are 58,000 psi. tensile strength, 55,000 psi. yield strength, and 10% elongation. It is expected that alloy 6262-T9 will replace 6061-T6 as the standard material for fasteners and specialty screw machine parts such as fittings, couplings, and components of cameras and other consumer products. *Aluminum Co. of America.*

For further information circle No. 2135 on literature request card, p. 48B

Heat and Corrosion Resistant Materials

Alumina Ceramic

"Diamonite", containing up to 97% alumina, is capable of withstanding repeated heating to 1000° C. (1830° F.) followed by air quenching. The material is well suited to applications involving low dielectric loss with high heat resistance, or resistance to corrosion, wear, and mechanical shock. Wet-forming presses are capable of producing parts up to 12 in. wide by 20 in. long. *Diamonite Products Mfg. Co.*

For further information circle No. 2136 on literature request card, p. 48B

Nuclear Materials

Nuclear System Heat Exchangers

Spent fuel elements from nuclear reactor installations continue to generate heat during shipment to reclamation plants. Special heat exchangers designed by *American Standard Industrial Div.* remove this heat efficiently. A primary circuit heat exchanger, made of Inconel, removes heat from the water-filled chamber containing the fuel elements. The secondary (external) circuit, made of copper-nickel alloy, isolates the irradiated cooling water and discharges heat to the atmosphere.

For further information circle No. 2137 on literature request card, p. 48B

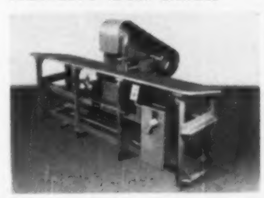
Cutting and Forming Equipment

Hollow-Bar Toolsteel

"Mineor FM" is a deep-hardening, nondeforming toolsteel (A.I.S.I. grade A-2) with free-machining properties. Izod impact strength (unnotched specimen) at Rockwell C-62.5 is 104 ft-lb. Minute, uniformly dispersed alloy sulphides impart good machinability without sacrificing strength or toughness. The hollow bar is available in sizes ranging from 2¼ to 16¼ in. O.D., ¾ to 9¾ in. I.D., and wall thicknesses from ¾ to 4½ in. *Darwin & Milner, Inc.*

For further information circle No. 2138 on literature request card, p. 48B

Abrasive Belt Head

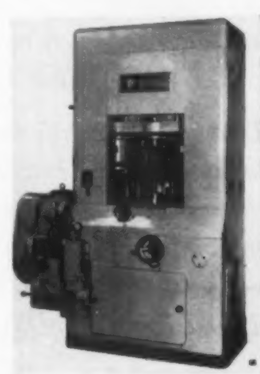


Belt life is increased with this machine because the abrasive belt travels on a resilient, driven, backup belt which supplies moving support as it crosses the work position. The adjustable table top can be positioned horizontally or tilted to produce a chamfer or a beveled edge on the material in process. *Murray-Way Corp.*

For further information Circle No. 2139 on literature request card, p. 48B

Powder Briqueting Press

A 40-ton crank-toggle press with 2⅜ in. depth of fill will dry-press powdered metals or ceramic, carbon, and other powdered materials. The press features a hydraulically controlled floating die table, infinitely variable control of relative bottom pressure, and an adjustable production rate of 10 to 19 strokes per minute. *Haller, Inc.*



For further information circle No. 2140 on literature request card, p. 48B

Air-Hardening Die Steel

Crucible Steel Co. of America announces a low-temperature, air-hardening die steel, "Orbit" (grade A-6). This tough, free-machining steel (40% better machinability than conventional oil-hardening grades) combines the advantages of air-hardening toolsteels with the low hardening temperature of oil-hardening grades.

For further information circle No. 2141 on literature request card, p. 48B

who cares about the core . . . *as long as the rest tastes good? This viewpoint can't be shared by users of stainless or high temperature alloys or tool steels. For production men who know anything about steelmaking . . . recognize that weak structure or poor composition at the core of an ingot can mean trouble with every piece of steel that comes from it. It can result in higher rejection rates, premature part failure, shortened tool and die life, increased production costs, and dissatisfied customers.*

That's why we say the exclusive MEL-TROL® process goes a step beyond quality control. It includes a new, patented ingot mold which controls the freezing process . . . forces impurities to the top where they can be cut off and discarded. This MEL-TROL ingot is more uniform . . . freer from segregation. You get clean, sound, tough metal from core to surface in every lot of steel you order. Use MEL-TROL Specialty Steels and enjoy the luxury of saying: "No problems . . . never a thought about cores!"

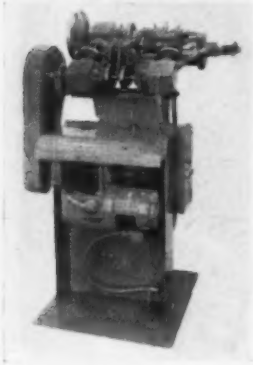
Carpenter steel

you can do it ***consistently*** better with Carpenter Specialty Steels for specialists

The Carpenter Steel Company, Main Office and Mills, Reading, Pa.
Alloy Tube Division, Union, N. J.
Webb Wire Division, New Brunswick, N. J.
Carpenter Steel of New England, Inc., Bridgeport, Conn.

Circle 2424 on Page 48-B

Ribbon and Wire Forming Machine



"Model RWI No. 00", capable of high-speed operation from a horizontal 0° position to a vertical 90° position, is used in producing small, precision formed parts for both small shops and large plants which have automatic production lines. The machine will accept up to 1/32 in. diameter steel wire and standard ribbon metal up to 3/16 in. wide. *Baird Machine Co.*

For further information circle No. 2142 on literature request card, p. 48B

Industrial Heating Equipment

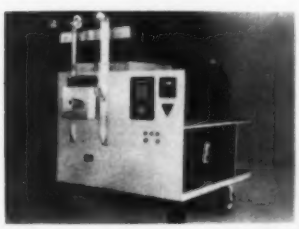
Infrared Control System

Featured at the Metal Show, this *Leeds & Northrup* multi-control system combines measurement and control of any of three heat treating atmospheres – CO, CO_2 and CH_4. The equipment can control from two to six generators, batch furnaces, or zones of continuous furnaces – or a combination of all three. All instruments, hardware, and cabinets are panel-mounted, piped and wired.

For further information circle No. 2143 on literature request card, p. 48B

Portable Electric Furnace

A portable electric furnace made by *Pereny Equipment Co.* will operate at temperatures up to 2900° F. It incorporates molybdenum disilicide elements, a strip chart recorder-controller, and a reset-type indicator with automatic temperature shut-off. The furnace chamber on the 26 kw. "FGKS Series" is 10 in. wide by 10 in. high by 30 in. deep.



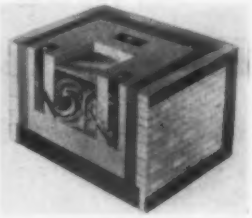
For further information circle No. 2144 on literature request card, p. 48B

Aluminum Melting Furnace

Sunbeam Equipment Corp. is introducing a dry hearth furnace for melting and holding aluminum. A sloping hearth and precise temperature control reduce porosity and scrap loss. Designed for use in permanent mold, sand, or die casting plants, the furnace can be built for operation with gas or oil, or a combination of both fuels.

For further information circle No. 2145 on literature request card, p. 48B

Cross-Channel Salt Bath Furnace



In this furnace, vigorous salt circulation is assured by forced circulation with "heat-pump" action through the sloping channels. A 12 in. square by 30 in. deep bath can easily heat 1200 lb. of steel to 1600° F. in 1 hr. with 100 kw. input. Inexpensive, easily replaceable electrodes requires no water cooling and low watt-density insures long electrode life. The high operating voltage eliminates the need for a furnace transformer. *Lindberg Engineering Co.*

For further information circle No. 2146 on literature request card, p. 48B

Cleaning and Finishing Equipment

Hot Spray Painting

Material savings of 30 to 50% can be realized with the "Chemtronic" spray process. A hydrocarbon compound is heated and vaporized into a dry gas, 2½ times heavier than air, which atomizes and aids in applying the paint. Coatings with greater "film build" and less sags are pos-

New Ease in Hardness Testing

with this Steel City Brinell Machine

● LOW-COST ● HYDRAULIC
● MOTORIZED
● POSITIVE ACCURACY

Now, even smaller shops can do Brinell hardness testing with a bench-mounted machine combining operating economy, control simplicity, high accuracy. Tests made with only finger-tip pressure. Operators cannot apply load too fast or overload. Stroke of ¾" permits anvil height to remain fixed when testing series of pieces of almost equal thickness. Load, provided by motorized hydraulic pump, is accurately controlled by time-tested relief valve. Load verified on sensitive hydraulic load gage.

Distributors in most major metalworking areas

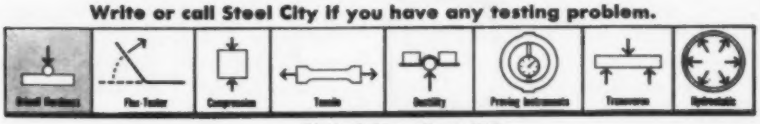
Steel City Testing Machines Inc

8811 Lyndon Ave., Detroit 38, Mich.

ALSO AVAILABLE IN DEAD WEIGHT MODEL

Either bench or floor-mounted, hand-operated or motorized. Operation is simple, fool-proof, with highest accuracy assured. Brinell loads can be changed frequently without loss of accuracy.

Write or call Steel City if you have any testing problem.



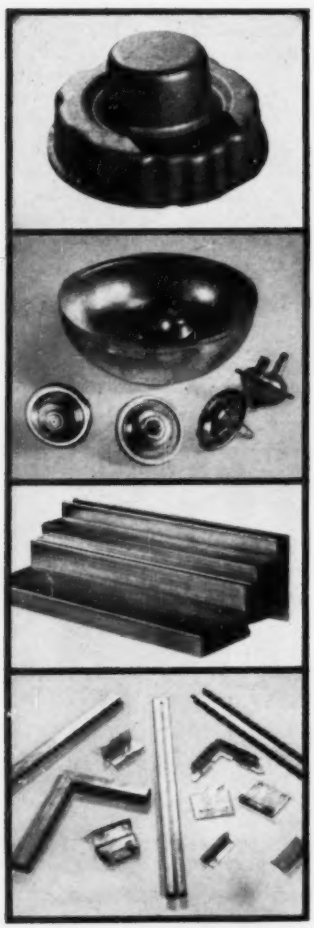
Circle 2425 on Page 48-B

ARMCO STEELS / for better products • lower costs

Galvanized Steel

Armco ZINCGRIP Steel Protects Against Rust and Corrosion at Minimum Cost

Special hot-dip zinc coating that doesn't flake or peel gives formed steel parts economical durability.

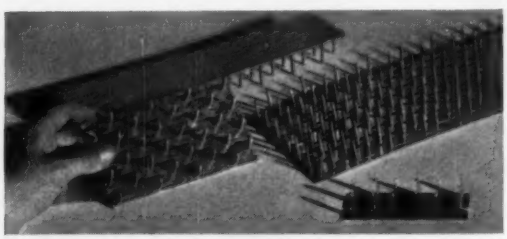


If you are making parts like these—parts that require the strength of steel yet must have low cost protection against rust—Armco ZINCGRIP Steel offers you opportunities to save money and improve product performance. Here's why:

* **ZINCGRIP STEEL has the lasting protection of a full-weight hot-dip zinc coating (1.25 oz. or heavier).**
* **The special coating on ZINCGRIP won't flake or peel despite forming, drawing, piercing, or other severe working.**
* **Armco's patented continuous process produces a zinc coating of uniform thickness and composition.**
* **For only a few cents' premium over cold-rolled steel, you eliminate the need for plating, painting or other protection.**
* **The economy and durability of ZINCGRIP STEEL has been service-proved in thousands of applications for more than 25 years.**

Let us send you complete information on Armco ZINCGRIP Steel so you can determine how its advantages can be most effectively used in *your* products. Armco Steel Corporation, 2370 Curtis Street, Middletown, Ohio.

New steels are born at Armco



ARMCO STEEL

ARMCO

Armco Division • Sheffield Division • The National Supply Company • Armco Drainage & Metal Products, Inc. • The Armco International Corporation • Union Wire Rope Corporation

Circle 2426 on Page 48-B

sible; in addition the process requires fewer spray passes and lower spray pressures. The method is applicable to all types of coatings, including metallic paints. *Fannon Products Co.*

For further information circle No. 2147

Painting Machine

Offering increased production and less down-time, a "painting machine" made by *Finish Engineering Co.* is well-suited to such production-line operations as prime and finish coating, baking, or vacuum metallizing. Since parts are handled on detachable carrier rods – 30 parts per rod – rejects from finger marks, and handling time, are reduced to a minimum. The speed of the machine is adjustable – up to 30,000 parts per hour can be coated – and either rotating or non-rotating work-holders can be employed.

For further information circle No. 2148 on literature request card, p. 48B

Chromate Conversion Coating

"Divercoat 2-A" produces a tightly adherent coating on all aluminum alloys without altering dimensions. On immersion, a protective chromate film develops from a chemical reaction between the aluminum and the solution. Used as a base for paint, or for decorative purposes, the conversion coating ranges in color from iridescent yellow to light gold – depending on the alloy and the conditions employed in processing the article. *Diversey Corp.*

For further information circle No. 2149 on literature request card, p. 48B

Ultrasonic Cleaning System

Increased cleaning speed and efficiency is obtained in ultrasonic cleaning systems with an automatic tuning feature on the generator, which instantly compensates for changes in load and liquid level.

The 20-kc. generators, with transistor circuitry, provide 250 to 1000 watts of power. In a modular arrangement these machines can generate up to 25 kw. *Acoustica Associates.*

For further information circle No. 2150 on literature request card, p. 48B

Welding and Joining

Powders for Plasma Spraying

The *Norton Co.* is offering a wide range of boride, carbide, nitride, and oxide powders for use in plasma arc-spraying equipment. To minimize powder feed problems, the particle size range is controlled to minus 150, plus 325 mesh. Four other powder size ranges are available for specific applications. Plasma spraying opens up many new possibilities for these compounds in applications where resistance to very high temperatures and corrosive environments is required.

For further information circle No. 2151 on literature request card, p. 48B

Controlled Angle Welding Torch

An inert-gas, tungsten-arc welding torch features a flexible body that can be adjusted to any angle or extended to reach into difficult recesses. This water cooled torch – rated at 180 amp. a.c./d.c. continuous duty – provides better and faster welding along with lower maintenance costs and less welder fatigue. *Falstrom Co.*

For further information circle No. 2152 on literature request card, p. 48B

All-Purpose Arc Welder

A "Muretran" a-c./d-c. inert-gas arc welding machine can be used for manual, automatic, inert-gas spot, or Sigma welding. A switch and dial control system permits rapid adjustment for process changeovers. The 21 kva welder – operating from 230/460 a-c. power – has a high fre-

NEW

KENTRALL HARDNESS TESTERS are Motorized

By removing major test loads automatically, the new motorized Kentralls reduce operator error, increase reproducibility of test results, and raise the productive capacity of the machine—for the same price as hand operated testers.

The motorized Kentralls are available in Combination Testers which provide both Regular and Superficial Rockwell Hardness Testing in a single machine. For those applications that do not require the additional range, Kentrall also makes single purpose testers for either Regular or Superficial testing alone.

For complete information write for Bulletin CRS 60

KENTRALL THE TORSION BALANCE COMPANY

Main Office and Factory: Clifton, New Jersey
Sales Offices: Chicago, San Francisco

TB163

Circle 2427 on Page 48-B

Another MX Test System at work...

A. J. De Vries, Magnaflux Field Engineer, checks up the Magnaflux installation at the Chicago Screw Company Division of Standard Screw Company with Hugh J. Maplesden, Superintendent of Inspection. Unit tests wide variety of high quality bolts and similar parts used in heavy equipment, diesel engines, stamping dies, etc.

Low Cost Testing with Magnaflux— Accessories Adapt to Low or High Volume!

This testing installation is a "productionized standard" Magnaflux unit. The basic standard unit, Model TAQ-524, is fitted here with a bath applicating device, a short conveyor for proper positioning and orientation of the parts and an accessory sequencing control cabinet. Reliability and reproducibility of test results are assured and the test operation is an efficient integral part of the plant operation.

An auxiliary conveyor unit carries the parts from the TAQ to the inspectors and on through automatic demagnetization. Thus, high production rates are easily attained, when required. Varieties of shapes and sizes are readily processed.

This is a specific example of a broadly applied concept: "productionize" any of the standard Magnaflux units by employing standard or easily adaptable auxiliary components, all available from Magnaflux Corporation.

Phone or write our local Field Engineer, or write to Magnaflux Corporation, 7322 West Lawrence Avenue, Chicago 31, Illinois.

MAGNAFLUX CORPORATION
A SUBSIDIARY OF GENERAL MILLS
General Mills
TEST SYSTEMS

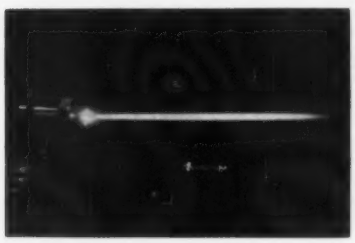
MX Test Systems include MAGNETIC PARTICLE, FLUORESCENT PENETRANT, THERMOGRAPHIC, EDDY CURRENT, ULTRASONIC, STRESS ANALYSIS, RADIOGRAPHIC TESTING, DYE PENETRANT & MAGNETIC FIELD

quency stabilizer, primary line contactor, separate control transformer, and thermal overload protection. *Metal and Thermit Corp.*

For further information circle No. 2153 on literature request card, p. 48B

Plasma Flame Torch

This quiet, low-velocity flame of helium plasma can generate temperatures up to 50,000° F. Direct impingement of the flame on molten metal causes no appreciable surface disturbance. The heat transfer rate



of the plasma stream is six times that of oxyacetylene. New applications for the flame are found in the fields of welding, melting, flame hardening, surface glazing, and materials testing. *Thermal Dynamics Corp.*

For further information circle No. 2154

Inspection and Control

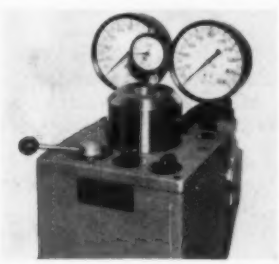
High-Temperature Load Cells

Compression and tension measurements can be made at temperatures up to 750° F. with weldable strain gages produced by *Micro-Test Inc.* The load cell can be compensated for such factors as low zero shift and change in modulus of load column with temperature. Ranges offered are 5000, 10,000, 20,000 and 50,000 lb., with an accuracy of ¼% of full-scale reading.

For further information circle No. 2155

Foil and Thin Sheet Tester

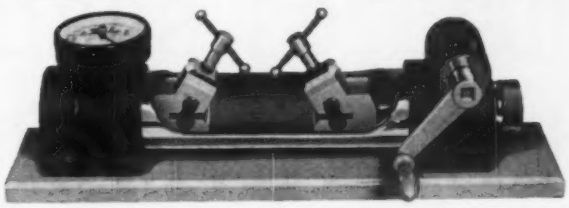
The "Model TSD" ductility tester is designed to obtain rapid, accurate



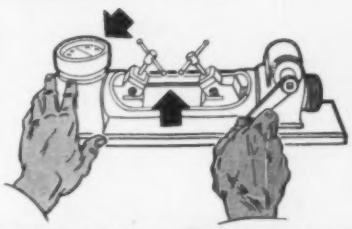
readings on thin sheet for experimental and production work. A variety of conditions can be set up on

Always Handy, A PORTABLE Tensile Tester

Use this compact, precision tensile tester to test strip steel, wire, bolts, spot welds, or anything else within its 4,000 lb. capacity. Use it in the shop, the lab, or in the field.



The maximum load requires only a moderate pull on the crank. Test results are easily read from the load gauge. Simple to use anywhere, any time. Write for catalog sheet and price.

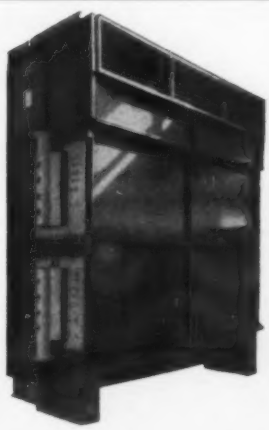


Information on other Detroit standard and special tensile testing machines, with up to 40,000 lbs. capacity, will also be sent upon request.

DETROIT TESTING MACHINE COMPANY

9384 Grinnell Avenue, Detroit 13, Michigan

Circle 2429 on Page 48-B



You Get Better Results IN HEAT TREATING!

● Use the NIAGARA AERO HEAT EXCHANGER to control the temperature of your quench bath and you remove the heat *at its rate of input,* always quenching at the exact temperature that will give your product the best physical properties.

The Niagara *Aero* Heat Exchanger transfers the heat to atmospheric air by evaporative cooling. It extends your quenching capacity without using extra water. It pays for itself with water savings.

You can cool and hold accurately the temperature of all fluids, gases, air, water, oils, solutions, chemicals for processes and coolants for mechanical and electrical equipment. You get closed system cooling, free from dirt and scale.

Write for Bulletins 120, 124, 132

NIAGARA BLOWER COMPANY

Dept. MP-12, 405 Lexington Ave., New York 17, N. Y.

District Engineers in Principal Cities of U. S. and Canada

Circle 2430 on Page 48-B

"All exposed and unexposed surfaces shall be of STAINLESS STEEL..."

Cafeteria and Executive Kitchen, *Continental Grain Co.*, Offices: New York City. Designed by *Designs for Business, Inc.*, New York, N. Y. Fabricated by *Stainless Food Equipment Co.*, Newark, N. J. Installed by *Ben Mernit*, New York City

The specifications for this executive cafeteria called for all kitchen metal surfaces, both exposed *and* unexposed, to be constructed of stainless steel. Only *lifetime* stainless steel can offer the durability and ease of maintenance necessary for maximum sanitation in food handling.

MICROROLD STAINLESS STEEL was chosen for its consistent uniformity of gauge, outstanding finish and well-known fabricating qualities.

Why not investigate the advantages of stainless steel for your next project?

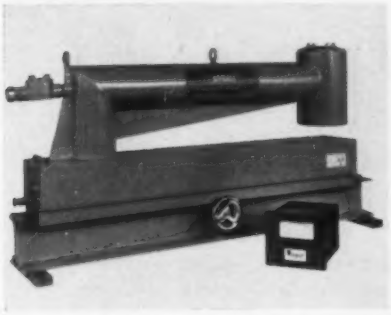
WASHINGTON STEEL CORPORATION

12-T WOODLAND AVENUE • WASHINGTON, PENNSYLVANIA

this flexible unit. The machine is available in five gage calibrations, ranging from 200 lb. to 2000 lb., and can test material ranging from 0.002 to 0.020 in. in thickness. *Detroit Testing Machine Co.*

For further information circle No. 2156 on literature request card, p. 48B

Beta Radiation Thickness Gage



The *Ohmart Co.* is introducing a control gage for measuring thickness variations in sheet materials – such as aluminum, steel, plastics, rubber, and paper – during processing. For very thin material (0.00075 in. aluminum; 0.002 in. paper) a krypton-85 source is employed. A strontium-90 source is used for thicker material (minimum values: 0.022 in. aluminum; 0.050 in. paper; 0.0065 in. steel).

For information circle No. 2157

Magnetic Particle Inspection Equipment

The "Portaflux" inspection unit provides either longitudinal or circular magnetization with coil and prod techniques. This portable 600 amp. (a-c.) generator requires only 10 amp. from a 110 v. line. The instrument, which will detect surface and near-surface flaws on all magnetic materials, is especially valuable in automotive and aircraft plants, tool and die shops, railroads, and pipe line installations. *Picker X-Ray Corp.*

For further information circle No. 2158 on literature request card, p. 48B

Production and Casting Equipment

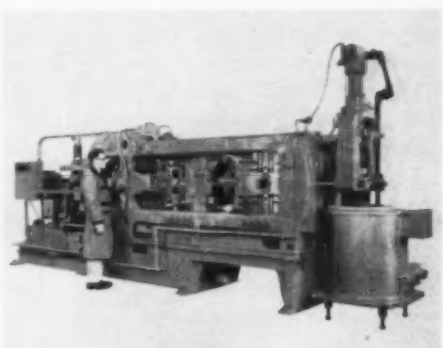
Dew Point Transducer

Alnor Instrument Co. is offering a transducer for measuring dew points from −20 to +60° F. The "Model 7600" is particularly suited to the continuous monitoring of endothermic gas generators. A millivolt output provides a choice of indicating, recording, controlling or alarm read-out. Minimum operator attention is required. Long life and system accuracy is assured – no moving parts. Thermometer elements are interchangeable.

For further information circle No. 2159 on literature request card, p. 48B

Zinc Die Caster

The 450-ton "Model HP450Z-SF" casting machine offers twice the die opening (adjustable stroke, 8 to 30 in.) of any machine with comparable clamping tonnage. The machine will produce "deep draw" zinc parts weighing up to 15¼ lb. Maximum die height is 30 in.; minimum height is 9 in. Cycle time is 5.7 to 7.5 sec. depending on die opening. *Lester-Phoenix, Inc.*



Circle No. 2160 on card

Parts and Forms for Design and Applications

High-Strength Fasteners

"Unbrako K-Series" alloy steel fasteners, cadmium plated, have twice the fatigue strength (40,000 psi.) of standard socket-head cap screws. The threads are rolled after hardening. All bearing surfaces are free of decarburization. K-Series fasteners are offered in standard screw diameter sizes, No. 8 through ½ in. Applications include aircraft accessories, turbines, and high-speed machine tools. *Standard Pressed Steel Co.*

For further information circle No. 2161 on literature request card, p. 48B

BRAZE BETTER!

use

AIRCOSIL NO. 18 FLUX with New Formulation

Silver alloy brazing turns out better when you use new *Aircosil No. 18 Flux*. Won't break down under long heat cycle up to approximately 1450°F. Chemicals stay in suspension, thanks to a new and improved formulation.

Won't spatter. Residue washes off with hot water. Long shelf life, because jar has new cover with flowed-in rubber seal. Supplied in ½, 1, and 5 pound jars; 30 and 50 pound containers.

For highest quality brazed joints on a wide range of ferrous and nonferrous alloys – use new *Aircosil No. 18 Flux*. Immediate delivery and complete information from your nearest Airco office or local distributor.

AIRCO AIR REDUCTION SALES COMPANY

150 East 42nd Street, New York 17, N. Y.
On the West Coast: Air Reduction Pacific Company
Divisions of Air Reduction Company, Incorporated
Authorized Distributors in most principal cities

Circle 2432 on Page 48-B

Nuclear Graphite Notes from

NATIONAL CARBON COMPANY

DIVISION OF UNION CARBIDE CORPORATION, 270 PARK AVENUE, NEW YORK 17, N.Y.

OFFICES: Birmingham, Chicago, Houston, Kansas City, Los Angeles, New York, Pittsburgh, San Francisco. In Canada: Union Carbide Canada Limited, Toronto

NO OTHER MATERIAL HAS SO MANY USEFUL NUCLEAR PROPERTIES

- EXCELLENT STRUCTURAL MATERIAL
- RESISTS CORROSION
- RESISTS THERMAL SHOCK
- EASILY FABRICATED
- HIGH MODERATING QUALITIES
- STRENGTH INCREASES WITH TEMPERATURE RISE

PRECISELY MACHINED GRAPHITE FOR THERMAL COLUMNS

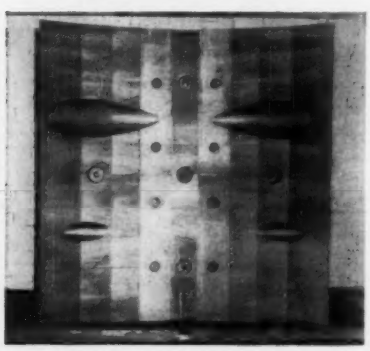


Photo shows inner wall of an 11 foot long graphite thermal column. Graphite was chosen for this installation because it is an excellent moderator of neutrons with low capture cross section.

This wall has 30 major blocks; the other 4 walls have 144 accurately machined blocks each. In all, 1300 precision machined graphite pieces are included in this thermal column. Close tolerances were held in machining each piece.

Many Universities are now using Graphite Moderated Training Reactors

Dr. E. F. Leonard, director of Laboratory Work for Columbia University, inserting a neutron source of plutonium-beryllium obtained from the Atomic Energy Commission.

A recently conducted survey shows that many universities throughout the country are using graphite exponential piles for training the sorely needed nuclear engineers of tomorrow. The survey also points out some of the advantages associated with graphite which are not found in other types of subcritical piles.

Graphite offers longer neutron diffusion (approximately 50 cm) and permits wider fuel rod spacing to assure accurate flux measurements. Also flux distortions are easily determined in graphite piles.

The structural and machineability features of graphite permit students to design and construct the pile. There are abundant experimental data and procedure history available on graphite (it's the oldest type of subcritical reactor) which permit more time for advanced experiments rather than basic fundamental experimentation.

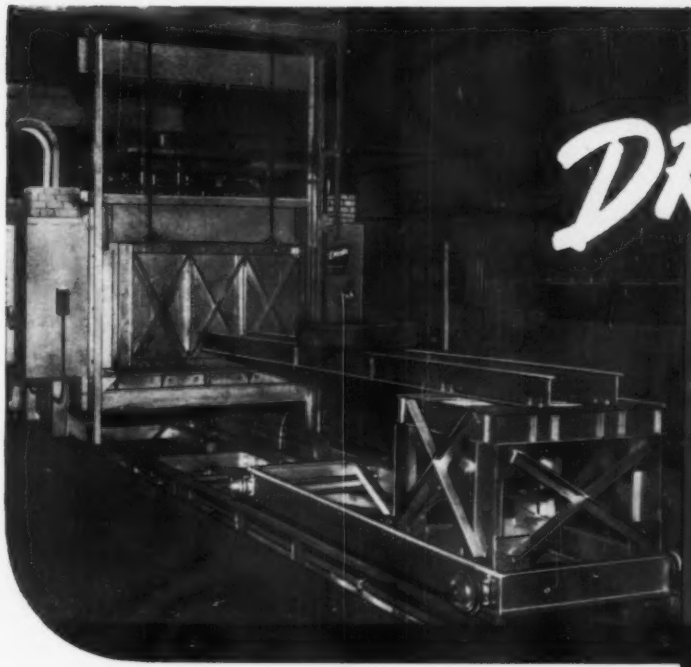
A graphite pile also offers considerable flexibility. It is easy to change configuration, to introduce voids, to accurately position samples, and the pile can be operated as either a bare or reflected system.

Dr. T. J. Thompson, professor of Nuclear Engineering at M.I.T., removing a plutonium-beryllium neutron source from the subcritical nuclear reactor.

"National" and "Union Carbide" are registered trade-marks for products of

NATIONAL CARBON COMPANY

UNION CARBIDE



DREVER

Stainless Wire Coil Annealers

Charge end of a Drever furnace for annealing stainless steel wire coils installed at the Stainless Steel Division of Jones & Laughlin Steel Corp., Detroit, Michigan.

After operator places coil on charge fork, the entire operation into the furnace and from the furnace into the quench is automatic.

Discharge end of furnace showing Tilting mechanism after coil has been discharged into quench.

Two quenches are supplied; water quench for 300 series and oil quench for 400 series.

Drever's gas-fired coil annealing furnace is designed to handle (4) 250 lb. coils of wire per hour. Coils vary from 36" to 48" O.D. in size and from 200 to 250 lbs. in weight.

Uniform and rapid heating of coils is accomplished with a minimum of scale formation.

Consult Drever engineers on your stainless wire, rod, bar, sheet, plate and strip heating problems.

DREVER COMPANY

RED LION ROAD and PHILMONT AVE., BETHAYRES, PA.

Engineering and Manufacturing Facilities

37

Circle 2434 on Page 48-S

There's one exactly right for you...*Vancoram Chromium Alloys*

Because chromium improves steels and irons in so many ways, it has become one of the most economical and widely used alloying elements. Depending on the application and the percentage used, chromium imparts such properties as strength, hardness, toughness and corrosion resistance. The presence of chromium carbides also results in excellent cutting properties and wear resistance.

Naturally, for such a broad range of applications, no one alloy can serve for all uses; consequently, VCA produces more than thirty different chromium products, each tailored to do a specific job! The latest Vancoram Products list covers analyses and applications. VCA's technical staff will help you select the best for your needs. Just write or call your nearest VCA District Office. Vanadium Corporation of America, 420 Lexington Avenue, New York 17, N.Y. • Chicago • Cleveland • Detroit • Pittsburgh

VANADIUM
CORPORATION OF AMERICA
Producers of alloys, metals and chemicals

VANCORAM

Circle 2435 on Page 48-B

DoALL tells how Lindberg equipment helps produce stainless steel gage blocks

For the DoALL Company, Des Plaines, Illinois, heat treatment of their Stainless Steel Gage Blocks was a most formidable problem. For lasting accuracy these blocks require extremely hard, wear-resistant surfaces, free from growth or shrinkage, as provided by nitrided stainless steel. Case depth must be controlled accurately and the core maintained at full toughness free of stresses. DoALL found the answer to this problem with a Lindberg Gas Fired Vertical Cyclone Tempering Furnace with a Nitriding Retort.

DoALL

Norman Silver, Chief Metallurgist, and Lindberg Vertical Tempering Furnace at DoALL Company.

NORMAN SILVER, Chief Metallurgist says, "Our Lindberg equipment supplies the uniformity of heat distribution and the fast accurate control that is needed for the exacting requirements of our product. The furnace responds to control almost instantaneously and maintains the temperature within plus or minus 5°. Its 38" diameter by 36" depth handles 200 to 300 pound loads for the desired production. Results obtained have satisfied us completely with this, the latest of our Lindberg furnaces".

Lindberg provides the most complete line of heat treating furnaces, fuel fired or electric, large or small, for every heat treating requirement. Your Lindberg Field Representative (see your local classified directory) will be glad to consult with you on your heat treating requirements or write us direct. Heat Treating Furnace Division, Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.

Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, South Africa, Spain, Switzerland and West Germany.

Circle 2436 on Page 45-I

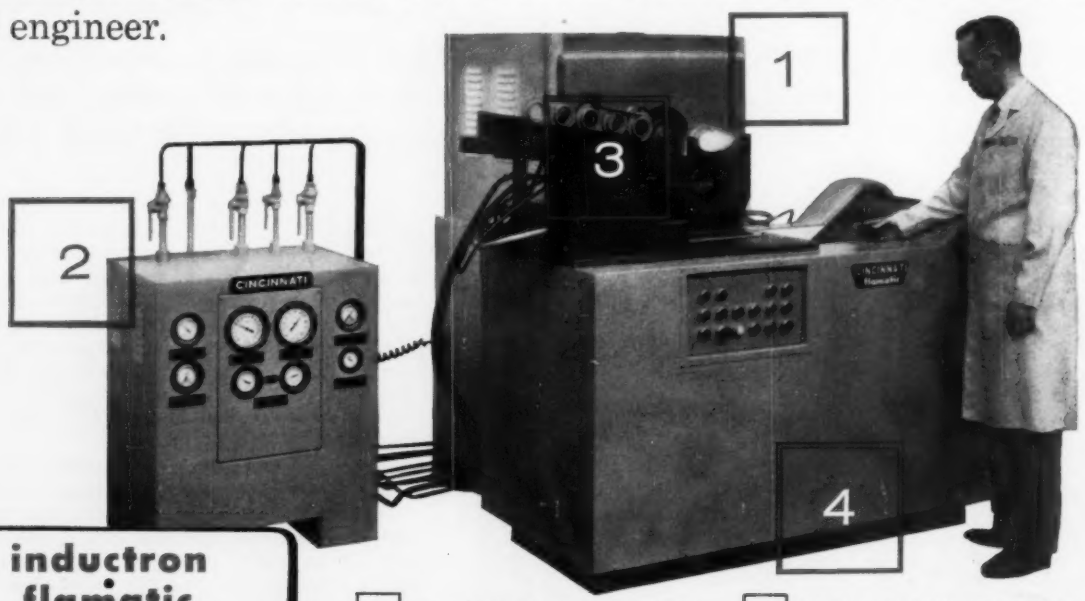
LINDBERG
heat for industry

CINCINNATI®

Advanced Heat Engineering turns four modules into a Flamatic . . .

Three standard components, plus expertly designed work-handling tooling, were quickly combined into this "custom-built" **Cincinnati Flamatic®**. It flame hardens the bore of SAE 1062 automotive stator hubs to 60-62 Rc. to a depth of 0.125", at a production rate of 208 parts per 52-minute hour.

Cincinnati Advanced Heat Engineering can solve your heating problems equally as fast and as economically. Modular design means earlier machine deliveries; allows speedy changes to be made as your applications change. As builders of **Inductron®** radio frequency and motor-generator types of induction heaters, as well as flame heating equipment, Cincinnati will give you unbiased counsel on the selection of heating machinery that best meets your needs. Let the benefits of **Cincinnati Advanced Heat Engineering** work for you. Call in a Meta-Dynamics Division field engineer.



inductron
flamatic
heating machines
META-DYNAMICS DIVISION
Machines for Metal Forming and Heat Treating
THE CINCINNATI MILLING MACHINE CO.
Cincinnati 9, Ohio, U.S.A.
CINCINNATI

1 FLAME HEAD UNIT is one of many standard types available. In this application, the unique rotary flame head is used, which advances and spins within the part bore.

2 GAS CONTROL CABINET is a low-cost unit containing all necessary regulating and metering equipment for fuel gases and oxygen, including accommodations for air and water.

3 WORK-HANDLING MECHANISM receives the part from a previous station by gravity. The fixture centers the part in front of the flame head. After heating, cradle tips, releases the part, and centers the next one.

4 FRONT BASE UNIT contains a quench tank, heat exchanger, quench agitation system, and an integral parts removal conveyor.

Circle 2437 on Page 48-B

NEW LITERATURE

Ferrous Metals

2164. Spring Steels
Brochure from *Sandvik Steel, Inc.* presents property and product data on various cold rolled or hardened and tempered strip steels for spring applications.

2165. 17-4PH Stainless
Armco Steel Corp. has published data on 17-4PH stainless steel; stronger than Type 416, with corrosion resistance in the 18-8 class.

2166. Leaded Steels
Aristoloy Steel Div. offers Products & Facilities Catalog discussing blooms, slabs, billets and bars, in carbon, alloy, stainless, and leaded steels.

2167. Die Form Blanks
Folder ADV-746 from *Republic Steel Corp.* discusses die form blanks which closely approximate the completed part, thus minimizing your production costs.

2168. Alloy for Electronics
16-p. data sheet on "Moly Permalloy" gives information on testing, hysteresis, heat treating, magnetization curves, core loss, graphs, plus physical, mechanical, and magnetic properties. *Allegheny Ludlum Corp.*

2169. Color-Coated Stainless
8-p. pamphlet from *Washington Steel Corp.* gives general information, characteristics, physical and mechanical properties, and applications for color-coated stainless steel sheet and strip.

2170. "Carbide Metals Review"
An article "Men, Metals and Markets" in the Spring 1960 issue tells about applications for stainless steel and titanium in transportation, architecture, process industries, and consumer goods. *Union Carbide Metals Co.*

2171. Nickel Steels
The International Nickel Co. will send a buyer's guide to steel service centers that stock 4340 and 4620 grades of steel.

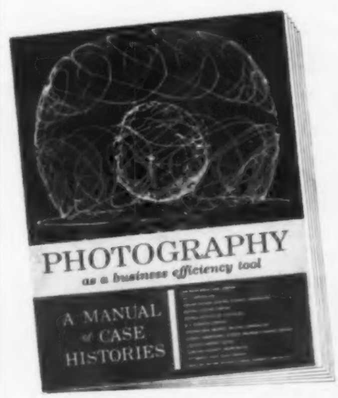
2172. Vacuum Melted Steels
Bulletin from *Allegheny Ludlum* on vacuum melted steels and alloys. Greater cleanliness, improved soundness, decreased gas content and enhanced mechanical properties.

2173. Steel for Springs
The *Ziv Steel & Wire Co.* will send product data on carbon spring steels and high-grade toolsteels.

2174. Films on Steel Products
Republic Steel Corp. offers a 33-p. illustrated catalog of 35 films covering a wide range of general interest topics on steel and its uses.

2175. Hydrogen Embrittlement
8-p. report presents specific recommendations for eliminating hydrogen embrittlement, including processing precautions for holding hydrogen pick-up within harmless limits in electroplated high-strength bolts and nuts. *Standard Pressed Steel.*

2163. Booklet from *Ansco* presents well-illustrated case histories on photography as an industrial tool – photo-instrumentation for rocket tests (materials and design), sheet metal layout by graphic arts techniques, research



via X-ray microscopy, engineering studies of fast-moving equipment via high-speed motion pictures, and transfer of printed circuit designs. Inspection and quality control are improved and speeded-up when advanced X-ray and photographic techniques are used.

2176. Steel Tubing
20-p. manual from *Pacific Tube Co.* details size ranges, mechanical and physical properties, tolerances, specifications, materials selection and applications of mechanical pressure, and aircraft tubing.

2177. Toolsteel Selector
The *Allegheny Ludlum* toolsteel "Steelector" booklet contains selector cards, descriptions of the various toolsteel grades, and explains individual "Data Stock lists" available for each grade.

2178. Alloy Steel Booklet
"Quick Facts About Alloy Steels" published by *Bethlehem Steel Co.* Elementary information on steel heat treatment, properties, and microstructures.

2179. Stainless Steel
Catalog *"Armco Stainless Steels"* discusses applications for stainless sheet, strip, bar, and wire in 60 analyses and a broad range of sizes and finishes.

2180. Austenitic Stainless
8-p. booklet explains nature and occurrence of sigma phase, as well as its chemical composition, identification, and effect on mechanical properties and corrosion resistance. *Electric Steel Foundry Co.*

Nonferrous Metals

2181. Zirconium Products
"Zirconium Data File" gives information on production of Zr and Hf, melting, wrought products, alloys and properties, fabrication, and applications. *Carborundum Metals Co.*

2182. High-Density Metal
Booklet describes "Fansteel 77" metal, a nonmagnetic, easily-machined alloy with maximum density. It is available in bars, rods, rings, disks, and special shapes. *Fansteel Metallurgical Corp.*

2183. Magnesium Products
Dow Metal Products Co. has 8-p. brochure on machining, forming, and welding characteristics of magnesium.

2184. "Tin News"
Monthly paper discusses new applications such as 2.5% tin in alpha titanium—the structural alloy in the X-15 manned rocket. Tin provides greater creep resistance. *Malayan Tin Bureau.*

2185. Murcurial Brass
Bridgeport Brass Co. announces "Alloy 77", a condenser tube alloy which reduces biofouling. Costly chlorination treatments are reduced.

2186. "Handbook of the Alloyist"
Discusses advantages of several groups of alloys used in the electrical and electronics industries. Properties and typical applications are given. *H. K. Porter Co.*

2187. Rare-Earth Chemicals
Vitro Chemical Co. offers brochure on rare earth metals, chemicals, and alloys—thoria, gadolinium oxide, cerium and scandium chemicals, and rare earth-magnesium alloys.

2188. Nickel Alloys
International Nickel Co. has application data and engineering information on nickel, its alloys, and the various grades of stainless for unusual conditions of stress, fatigue, heat or cold, or corrosion.

2189. Beryllium Tubing
Data Memorandum 26 published by *Superior Tube Co.* contains information on Be tubing—sizes, physical and mechanical properties, composition limits, nuclear applications.

To request any item listed, circle appropriate number on Reply Card, p. 48B

CARBORUNDUM'S TECHNICAL INFORMATION ON UNUSUAL REFRACTORIES **Data sheet**

How to choose materials for

WEAR RESISTANCE

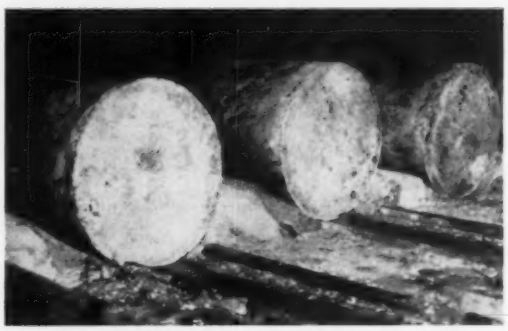
Choice of a material to give optimum wear resistance requires knowledge of type of wear (e.g. abrasion or erosion), effect on different materials, and presence of such factors as load, corrosion, thermal shock etc.

The two basic types of wear (examples shown at right) are (1) impingement of fine solids entrained in air, gas, or other fluid and (2) direct sliding of a solid mass across a surface. Effects may be erosion, primarily of the bond, thus dislodging the harder body granules; minute progressive bond fracture due to impact; or chipping, gouging or grinding of monolithic materials.

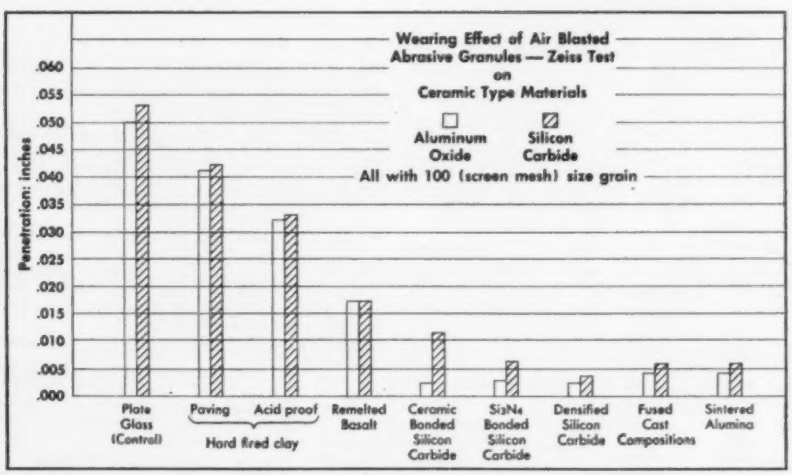
Refractories manufactured by Carborundum from electric furnace materials — such as silicon carbide and alumina — offer excellent wear resistance (see chart). Moreover, they are chemically inert, resistant to spalling, and have superior load-carrying capacity. As a result, they have found extensive use in dust collectors, gas scrubbers, transfer pipelines, hydro-cyclones, etc.

Carborundum's accumulated experience and data may help solve your wear problems. Feel free to ask for any assistance.

Abrasion by more than 2,500,000 pounds of sinter dust in 7 years has been resisted by the CARBOFRAX® silicon carbide lined cone of this primary dust collector. By comparison, other brick in the scroll and in the course between scroll and cone have been worn back to the shell, in one area after only 5 months.



Skids of CARBOFRAX® silicon carbide lasted 156 weeks under heat and the abrasion of 6¼" x 8" brass billets in this gas-fired extrusion mill furnace. Steel skids averaged only 5 weeks life.



Write today for your free copy of "Super Refractories by Carborundum." The address: Dept. M-120, Refractories Div., Perth Amboy, N. J.

Information adapted from Chart 1, Carborundum **"REFRACTORIES"** Vol. 1, No. 6, December 1956. This bulletin, containing extensive technical information on the properties and application of refractory-type products, is published bi-monthly. Complimentary subscription on request.

For engineered refractories, count on **CARBORUNDUM®**

Circle 2438 on Page 48-B

2190. Rare-Earth Metals

Brochure from *Lunex Co.* contains information on high-purity rare earth metals including neodymium, yttrium, and lanthanum.

2191. Extrusion Dies

General Extrusions, Inc. has issued a 40-p. catalog listing 700 stock dies for aluminum extruded shapes, rods, bars.

2192. High-Strength Bronzes

20-p. bulletin gives specifications on nine special wear and corrosion resistant, copper-base alloys. *Ampco Metal, Inc.*

2193. Cobalt and Nickel-Base Alloys

4-p. data sheet lists physical and mechanical properties, corrosion resistance, thermal treatments, fabricating data, available forms, and applications of 13 alloys. *Cobalt Information Center.*

2194. Platinum Products

Catalog No. 5 describes complete line of platinum products from *J. Bishop & Co.*

2195. Book on Indium

The Indium Corp. of America will send bulletin which describes a 770-p. reference book on indium.

2196. Lithium

The *Lithium Corp. of America* has pamphlet which discusses the aging effect of aluminum-copper-lithium alloys, and the mechanical properties of aluminum-lithium alloys.

2197. Bronze Castings

The American Smelting and Refining Co. will send pamphlet discussing "Asarcon" continuous-cast bronze products.

2198. Rare Earths

Bulletin "Rare Earth and Yttrium Metals" has been published by *Lindsay Chemical Div.* . . . discusses properties, purities and costs.

Heat and Corrosion Resistant Materials

2199. Refractory Metal Chart

Offered by *Fansteel Metallurgical Corp.* Lists the properties of the elements tungsten, tantalum, molybdenum, and columbium.

2200. High-Temperature Alloy

16-p. booklet discusses "Haynes Alloy 56", a lower-cost, high-temperature alloy with good strength and oxidation resistance in the 1200-2000° F. range. *Haynes Stellite Co.*

2201. Superalloy

"René 41" is vacuum-induction melted for higher strength and ductility. The alloy can be forged, welded, or formed. Details available from *General Electric.*

2202. Refractory Metal Parts

Isostatic pressing and sintering of tungsten and molybdenum powders produces high strength parts for high-temperature —such as rocket nozzles. *Sylvania Electric Products* has the details.

2203. Heat-Resistant Castings

Electro-Alloys Div. has published a brochure on "Supertherm", a heat resistant 26% Cr-35% Ni alloy for castings operating in the 1800-2300° F. range.

2204. Ceramic Coating

Norton Co. has published a booklet on "Rokide" coating process which protects parts against abrasion and temperatures to 4600° F. range.

2205. René 41

Technical Bulletin No. 86 discusses René 41, the most dependable alloy in use today in the 1200 to 1800° F. range. *Cannon-Muskegon Corp.*

2206. Thermal Fatigue

Electro-Alloys Div. will send you a report entitled "The Mechanism of Thermal Fatigue", by H. S. Avery.

2207. Super Refractories

The Refractories Div. has published "Super Refractories by *Carborundum*" which contains application and property data on special refractories.

2208. Heat Resistant Castings

The International Nickel Co. will send 64-p. booklet "Heat Resistant Castings, Corrosion Resistance Castings. . . . Their Engineering Properties and Applications".

2209. Corrosion Data Charts

The corrosive effects of 400 different moterials on 16 different alloy systems — including Hastelloys, Monel, Nickel, Inconel, aluminum, tantalum, titanium and zireonium—are shown in data chart published by *Nooter Corp.*

2210. Silicon Carbide

The *Norton Co.* will send details on "Crystolon 63", a nitride-bonded silicon carbide.

2211. Corrosion Resistant Alloys

Bulletin No. 571 from *General Alloys Co.* presents their line of corrosion resistant alloys. Chemical analysis, mechanical properties, and A.S.T.M., A.C.I., A.I.S.I. and S.A.E. specifications are compared.

Radiation and Nuclear Materials

2212. Beryllium Oxide

The *Brush Beryllium Co.* will send booklet containing information on beryllium oxides — favorable nuclear, thermal, and dielectric characteristics.

Tool Materials

2213. Toolsteel Guide

Written by Dr. B. L. Averbach of M.I.T., "Toolsteels", a basic guide to the use of tool and die steels has been published by *Climax Molybdenum Co.*

2214. Band Saws

Details from *Armstrong-Blum Mfg. Co.* on "Marvel No. 81" series band saws for lowering production costs.

2215. Toolsteels

Bethlehem Steel Co. will send illustrated Booklet No. 532 covering oil and air-hardening toolsteels.

2216. Colloidal Dispersions

Bulletin 425 discusses colloidal dispersions for reducing costs in metal casting operations. *Acheson Colloids Co.*

2217. Roll Forming

The Yoder Co. has published 88-p. illustrated booklet describing cold-roll-forming equipment, processes, and complete line of products.

2218. Drop Forging

Chambersburg Engineering Co. will send brochure, "The Automatic Production of Forging in Closed Dies".

2219. Die Protectors

Bulletin 5107 from the *Clark Controller Co.* covers a complete line of electronic die protectors for punch presses. Die damage due to double heading is prevented.

2220. Die Steel

Data sheet presents characteristics and applications of "Hardtem", a chromium-

Circle appropriate number on Reply Card, p. 48B

No Corrosion Problem on Mild Steel Parts!

Stainless Overlay Cuts Costs, Keeps Quality High

Case in Point: Major outboard motor manufacturer, caught in cost-price squeeze, wanted to fabricate his stainless drive shafts from mild steel but didn't know how to lick the corrosion problem. Wall Colmonoy supplied the answer: Nicrocoat Processing. The shaft was sprayed with Nicrocoat No. 3 Alloy which was then furnace fused to form a molecularly bonded smooth coating. The result was a mild steel shaft with corrosion resistance equal to solid 400 grade stainless steel (and with even better wear resistance). The work was done at our Detroit plant.

Wear resistance was improved when outboard motor drive shaft was fabricated of mild steel with front 6 inches clad with Nicrocoat No. 3 Alloy.

Nicrocoat Processing Benefits:

- **Finish machined parts may be dipped or sprayed for overlays as thin as .0002".**
- **Stainless coating is furnace fused—overlay gives long trouble-free part life.**
- **Mild steel costs less, is less expensive to machine than stainless.**
- **Stainless coating covers completely, leaves no unprotected edges. It fills cracks, seals porous castings.**

Call or write for full information on how our stainless processing facilities can help you.

WALL COLMONOY CORPORATION

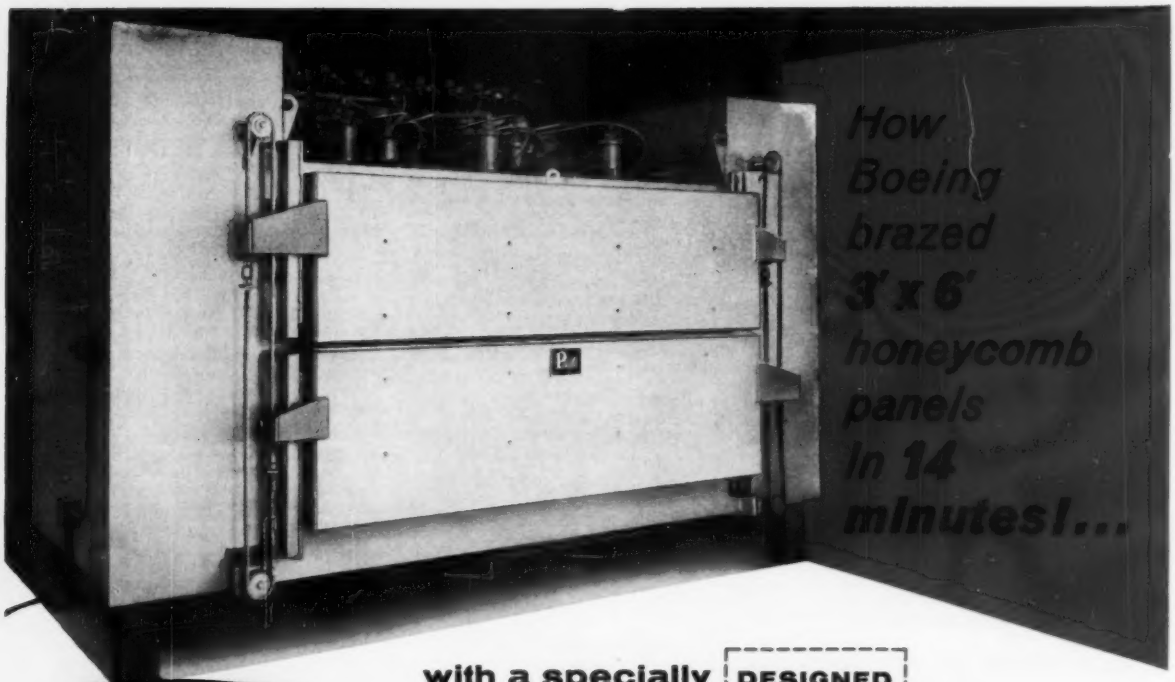
Stainless Processing Division

19345 JOHN R STREET • DETROIT 3, MICHIGAN

Representatives in all key industrial areas

PROCESSING PLANTS: Detroit, Michigan • Morrisville, Pennsylvania • Dayton, Ohio • Montebello, California

Circle 2439 on Page 48-B



with a specially DESIGNED

RAPID-HEATING PLATEN FURNACE

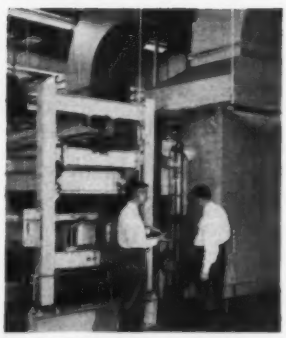
In operation since March 1959, this gas fired Pacific Platen Furnace has provided Boeing Airplane Company with a super-fast method for brazing honeycomb. Teamed with a Boeing press quench, the Pacific furnace has brazed three by six foot steel honeycomb panels within 14 minutes after the start of the heating cycle with thermal gradients as small as ±15°F. at 1675°F.

Charging and discharging operations are swift and simple. The furnace door opens in two sections to save seconds and the honeycomb retort is withdrawn into the press quench positioned directly in front of the furnace. Here the honeycomb is rapidly quenched to room temperature.

The press quench brazing technique eliminates use of graphite reference forms; therefore, much swifter heating can be achieved. Two banks of flat flame burners with eight burners in each bank bring the furnace up to heat in a hurry. Total capacity is 8,000,000 BTU/Hr.

Pacific engineers worked in co-operation with Boeing to produce this excellent solution for fast honeycomb brazing. If you have a similar need or a heat treating problem of any kind, Pacific will be happy to work with you to provide the best furnace to fit your needs.

Call or write now for further information.



Boeing press quench, shown in front of Pacific Furnace, shapes and quenches honeycomb assemblies in one operation, eliminating graphite reference forms.

FURNACE FEATURES INCLUDE:

- Temperatures to 2350°F.
- 8,000,000 BTU/Hr. capacity
- Removable heating sections
- Two zones of control

Pacific ®TRADE MARK

Creative Development and Manufacturing in Furnace Design

GAS OR ELECTRIC INDUSTRIAL HEAT TREATING EQUIPMENT

PACIFIC SCIENTIFIC COMPANY

LOS ANGELES
SAN FRANCISCO
SEATTLE
PORTLAND, OREGON
ARLINGTON, TEXAS
SAN DIEGO
DENVER

PACIFIC SCIENTIFIC COMPANY, P.O. Box 22019, Los Angeles 22, Calif.

☐ Please send me information on custom designed furnaces.

☐ Please send me your FREE Brazing Catalog.

☐ Please send me a copy of your new catalog and full information on Pacific Heat Treating Equipment.

Name_____

Company_____

Address_____

City_____ Zone____ State_____

Circle 2440 on Page 48-B

molybdenum-vanadium alloy die steel for hot-forging applications. *Heppenstall Co.*

2221. Bar Cutting

Brochure from *Salem-Brosius, Inc.* describes "Reactron" torque-cutting cut-off machine for bar stock, which produces no loss of metal, or cracked or split ends. Cuts are smooth, square and clean.

2222. Powerspinning

Bulletin release by *Metal Spinning Div.* discusses "Phoenixspun Powerspinning", for economical and accurate spinning of tough alloys in thicknesses up to 2 in. and diameters to 170 in.

2223. Toolsteel Identification

The *Gorham Tool Co.* has published their ninth edition of a 26-p. booklet covering classifications and symbols for identification of high-speed steels.

2224. "Moly" Lubricant

Bulletin 126 from the *Alpha-Molykote Corp.* gives the advantages of "Molykote G" lubricant. Free sample also offered.

2225. Tool and Die Steel

12-p. brochure contains information on "Lo-Air", a low-temperature, air-hardening tool and die steel which reduces grinding and machining time. *Universal Cyclops Steel Corp.*

2226. Lubricant For Forminng

Flyer from *Baker-Gubbins Co.* discusses "Compound 776-W", a water-soluble machining concentrate which allows high-heat-producing processes such as tube finning, tube-roll forming, and broaching to run cooler and cleaner.

2227. Toolsteel Selector

Peninsular Steel Co. has released a 28-p. toolsteel comparison guide which includes a complete index reference listing steels by trade names, A.I.S.I.-S.A.E. classification, and number.

2235. Box Furnaces

Bulletin GED-4179 from *General Electric* describes their box furnace for production heat treating for laboratories and for pilot operations.

2236. Program Controls

When temperature uniformity is a must, reproduce your heat treating cycles with new "master-slave" program control. Information from *Leeds & Northrup.*

2237. Gas Alloying

Lee Wilson Engineering Co., Inc. will send complete data on gas alloying. Carbon or nitrogen can be added or removed during the annealing operation.

2238. Thermocouple Alloys

Chromel - Alumel thermocouple alloys are accurate over the operating range from − 300° to + 2300°F. *Hoskins Mfg. Co.* will send information.

2239. Industrial Furnaces

Bulletin 461 discusses "Standard Type LR Preheat and CG Superheat" furnaces for all hardening and annealing applications. *C. I. Hayes, Inc.*

2240. Pyrometer Supplies

Complete data from *Bristol Co.* on full line of pyrometer supplies and accessory equipment.

2241. Industrial Furnaces

Flyer from *Sunbeam Equipment Corp.* covers line of furnace equipment including automatic shuffle hearth.

2242. Flame Hardening

12-p. illustrated brochure discusses problems of flame hardening and describes a complete line of equipment for the process. *Air Reduction Sales Co.*

2243. "Panelcoil" Heating

Data sheets M12 and M13 describe applications of *Dean Products* panelcoils for heating and cooling processing tanks, drums, troughs, and ovens.

2244. Pyrometers

Control instruments for the metal industry provide the key to higher quality, more uniform production, and greater efficiency. Data available from *Bristol Co.*

2245. Temperature Controls

Complete information from *Alnor Instrument Co.* on their "Pyrotroller" an electronic temperature controlling instrument for heat-processing operations.

2246. Bimetal Thermostats

Bulletin 1000 from *Stevens Mfg. Co.* describes "Stemco Type S" bimetal thermostat and gives industrial applications.

2247. Optical Pyrometer

Brochure on "Pyro-Eye," a two-color optical pyrometer for fully automatic, continuous measurement and control of high temperatures in the range of 1400 to 4500°F. *Instrument Development Laboratories, Inc.*

2248. "Tips and Trends"

Periodical published by *Ajax Electric Co.* gives application and processing news on salt baths for heat treating operations.

2249. Automatic Heat Processing

16-p. Bulletin S-1058 describes automatic heat processing equipment for heat treating, hardening, brazing, soldering, and annealing. *Selas Corp. of America.*

2250. Furnace Fixtures

The *Wiretex Mfg. Co.* will send a data sheet illustrating parts-holding fixtures for four types of heat treating furnaces.

2251. Indicating Controllers

Wheelco Instrument Div. will send complete details on their "Double-O" recording and indicating controller.

Circle appropriate number on Reply Card, p. 48B

Industrial Heating Equipment

2228. "Heat Treat Review"

Contains discussion of new developments in high-temperature gas carburizing, including heating curves, photomicrographs of test samples, and illustrations of carburizing equipment (Vol. 11, No. 2). *Surface Combusion Div.*

2229. Atmosphere Control

The *Electric Furnace Co.* offers good 12-p. booklet "Practical Aspects of Atmosphere Control" by R. J. Perrine, their Director of Research.

2230. CO_2 Cooling

Nine advantages of extremely fast CO_2 cooling over mechanical cooling presented in Booklet C7 from *Cardox Div.* Five other methods of reducing test chamber temperatures with CO_2 are diagrammed.

2231. Low-Temperature Cabinets

Folder from *Revco, Inc.* sets forth specifications on ultra low-temperature (to −140°F.) equipment for research, storage, testing, and production operation. Models available with thermal capacities up to 1300 Btu/hr. at 70°F.

2232. Heat Treating Chart

Tempil Corp's four-color chart, "Basic Guide to Ferrous Metallurgy," illustrates forging, burning, annealing, transformation, stress-relieving, nitriding, blue brittle, normalizing, and carburizing ranges, as well as grain size changes vs. temperature.

2233. Furnace Tubes

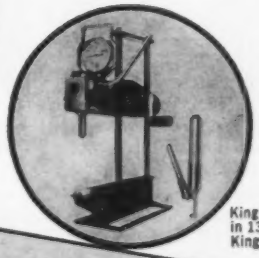
All-sheet construction adds to furnace tube life and minimizes burn-out. Data from the *Pressed Steel Co.*

2234. Selector Switches

Thermo Electric Co. will send Catalog 24-16 on thermocouple selector switches for fast, accurate indication of temperature from a number of thermocouples.

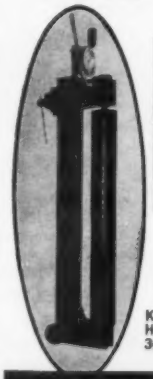
MAKE ALL BRINELL HARDNESS TESTS WITH The KING PORTABLE TESTER

King Test Head with Chain Adapter



King Test Head in 13½" base with King Brinell Scope

ONE TEST HEAD FITS MANY INEXPENSIVE ADAPTERS



King Test Head in 30" base

King Bore Brinell with small test head for pipes, cylinders, etc.

The KING PORTABLE HARDNESS TESTER

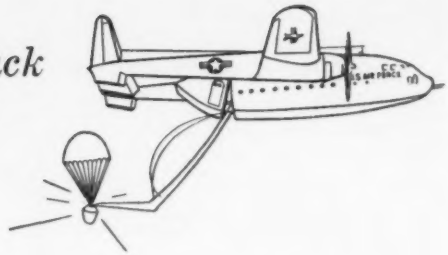
- To test any size, shape or thickness of metal.
- Makes guaranteed accurate on-the-spot tests — anywhere!
- Gap 10" — 13½" — 30". Throat 4" — 6¾" or larger with chain adapter.
- Loads from 62½ Kg. to full 3000 Kg. 5mm or 10mm steel or carbide ball.
- Will make tests in places no other tester can reach—including cylinder bores.

Write for literature and prices to Dept. MP-1260

KING TESTER CORPORATION 440 N. 13th St. Phila. 23, Pa.
Known the world over for accuracy and dependability

Circle 2441 on Page 48-B

finding the golden needle in the haystack



(Top right) *sketch illustrates mid-air catch of returning Discoverer XIV nose cone snagged by an airplane-towed "skyhook."* (left) *A captured practice capsule is slowly reeled towards the rear opening of airborne C-119 Recovery Plane.*

NOSE CONES PLATED WITH SEL-REX BRIGHT GOLD* RECOVERED FROM SPACE ORBITS!

Orbiting the globe, then returning earthward upon signal, Discoverer XIV's space capsule plummeted home to be snatched from the heavens in an historic mid-air catch!

U.S. teamwork had plucked the nose cone from a million miles of firmament—marking a significant stride forward in the Free World's space program.

The returning space capsule was plated with Sel-Rex Bright Gold. So was its predecessor, Discoverer XIII, which had been rescued earlier from the Pacific Ocean.

This patented plating process was applied by Philadelphia Rust-Proof Co., Inc. to provide maximum heat reflectivity and emissivity, under sub-contract from General Electric Company, Missile and Space Vehicle Department. Sel-Rex precious metal plating processes, in fact, are included in the original specifications of many advanced Space Age projects.

As producer of the world's largest selection of precious metal processes, Sel-Rex offers unique dependability to users of its plating systems. For, Sel-Rex engineers have removed the guess work, instead assure you of consistent plating quality, the quality that counts in critical areas.

Sel-Rex sales and service technicians throughout the Free World are ready to serve you with unmatched professional precious metal plating services.

Technical literature free on request. Specify precious metal(s) and your application.

(Above) *President Eisenhower holds American flag which was in recovered capsule during its flight through space. Capsule shown was electroplated with patented Sel-Rex Bright Gold Process. With the President are General Thomas D. White, Air Force chief* (center) *and Col. Charles G. Mathison, who directed the "capsule chase."*

**Patented*

Patented processes for plating with Gold, Rhodium, Platinum, Paladium, Silver, and to produce "custom alloys" for your particular requirements.

Sel-Rex

SEL-REX CORPORATION
NUTLEY 10, NEW JERSEY
World's largest selling precious metal plating processes

Circle 2442 on Page 48-B

2252. Radiant Tubes

Use wrought-cast radiant tubes for consistent, long life in furnaces. Literature from *General Alloys Co.* gives complete details.

2253. Conveyer Furnaces

Drever Co. has published a brochure covering controlled atmosphere conveyer furnaces. Temperatures to 2100°F.

2254. High-Temperature Furnaces

The *Pereny Equipment Co.* will send bulletin discussing complete line of furnaces for producing temperatures from 500 to 5000°F.

2255. Heat Treat Furnaces

Bulletin SC-182 describes power convection equipment and tells how it will increase speed and uniformity of heat treatment. *Surface Combustion Div.*

2256. Induction Heating

56-p. catalog describes "Ther-Monic" induction heating equipment for hardening, brazing, forging, annealing and melting. *Induction Heating Corp.*

2257. Automatic Furnaces

The *American Gas Furnace Co.* will send details on "Automotion" furnaces which operate automatically and continuously in a production line.

2258. Melting Furnace

The *Selas Corp. of America* will send information on a 300 lb. per hr., single-well batch furnace for melting high-purity aluminum.

2259. Induction Stirrers

Asea Electric Inc. has published literature on induction stirrers for promoting greater homogeneity and uniform temperature control.

2260. Production Carburizing

Bulletin P-59 describes line of pusher furnaces for production carburizing, which feature baffles for 100% forced convection heating. *Ipsen Industries, Inc.*

2261. Aluminum Billet Heaters

Bulletin HT-53 contains information on continuous conveyer-type aluminum billet heating furnaces. Capacity: 2500 lb. per hr., heated to 1000°F. *Carl Mayer Corp.*

2262. Indicating Thermometers

The Electric Autolite Co. will send data on their dial-indicating thermometers which feature raised graduations to reduce parallax error.

2263. Temperature Indicators

"Thermomelt" temperature indicators are accurate to within ± 1%. Available as crayon, liquids, or pellets. Literature from *Markal Co.*

2264. Induction Melting Furnaces

Hevi-Duty will send information on their induction melting furnaces for steel, cast iron, aluminum, copper, and magnesium alloys.

2265. "Heat Treat Review"

Volume 11, No. 3, from *Surface Combustion Div.* features a discussion of types of equipment used in continuous processing of ferrous and nonferrous strip.

2266. Themostats

Bulletin 6100 describes *Stevens Mfg. Co.* line of "Type MX" thermostats featuring narrow differentials.

Cleaning and Finishing Equipment

2267. Barrel Finishing Compounds

Allied Research Products, Inc. will send information on a line of barrel finishing compounds for finishing all types of metal or plastic parts.

2268. Alkaline Detergent

Bulletin F-9773 contains details on "Oakite 161," an alkaline detergent specially designed for safe pressure-spray washing of most metals — aluminum, white metals, brass and steel. *Oakite Products, Inc.*

2269. Etching and Plating

Brochure from *Eastman Kodak Co.* on etching, chemical milling, and plating with "Metal-Etch Resist."

2270. Conversion Coatings

Data files from *Allied Research Products, Inc.* gives advantages in using "Iridite" chromate conversion coatings for zinc and cadmium products.

2271. Vapor Degreasing

36-p. bulletin explains how to get more and better vapor degreasing for your money with "Nialk Trichlor." *Hooker Chemical Corp.*

2272. Industrial Blowers

Catalog No. 126C from the *Spencer Turbine Co.* describes complete line of blowers for all types of furnaces.

2273. Electrocleaner for Die Castings

Bulletin 860 presents data on "Clepco 50-ZB" for cleaning and conditioning zinc die castings. *Frederick Gumm Chemical Co.*

2274. Heat Resistant Paint

4-p. flyer gives story on "Heat-Rem H-170" which has resistance to temperatures up to 1700°F. *Speco, Inc.*

2275. Batch Cleaning

12-p. booklet discusses industrial batch cleaning in detail. The original pneumatically agitated cleaning method. *Magnus Chemical Co.*

2276. Airbrasive Unit

S. S. White Industrial Div. has published Bulletin 6006 on an industrial airbrasive unit. The cool, shockless, precise way to cut, abrade, deburr, and clean hard, brittle material.

2277. Barrel Finishing

4-p. brochure describes line of barrel-finishing compounds, abrasives, soaps and general media for both wet and dry tumbling operations. *Tumb-L-Matic, Inc.*

2278. Airless Spray Painting

Cut painting costs and at the same time get better finish quality. Brochure explains hot airless spray painting. *Nordson Corp.*

2279. Selective Plating

Production and repair plating without using immersion tanks enables you to (a) precision-plate selected areas economically without disassembling components, and (b) deposit metal rapidly where ordinary electroplating is difficult. *Sifco Metachemical, Inc.*

2280. Strip Mill Scrubber

Hanson-Van Winkle-Munning Co. will send flyer illustrating their various types of strip mill scrubbing equipment.

2281. Gold Spray Finish

Folder from *Bee Chemical Co.* describes bronzeless gold spray finish, which simulates the appearance of fine bronze powders.

2282. Resin For Baking Finishes

Data released by *Rohm & Haas Co.* covers "Acryloid AT-50," a thermosetting acrylic polymeric resin for high quality baking finishes.

2283. Blast Cleaning

"LM" blast cleaning table rooms will double the capacity of your cleaning de-

Circle appropriate number on Reply Card, p. 48B

MINIMIZE BURN-OUT...
PSC's All-Sheet Construction Adds to Furnace Tube Life
Experience of users shows much lower frequency of burn-out, with tube life extended up to 100%. In PSC tubes, precision-welded bends are of same metal and thickness as the legs. The continuously smooth walls result in uniform flow of gas, and reduce the carbon build-up and bend burn-out, which commonly result from the rough interiors of cast alloy bends. Lighter than cast by 33 to 50%, PSC radiant tubes cost less initially. Any size, shape or alloy.
All Types Heat-Treat Units
PSC
THE PRESSED STEEL CO. • Wilkes-Barre, Pa.

Circle 2443 on Page 48-B

On Inert Gas Producers, also . . .

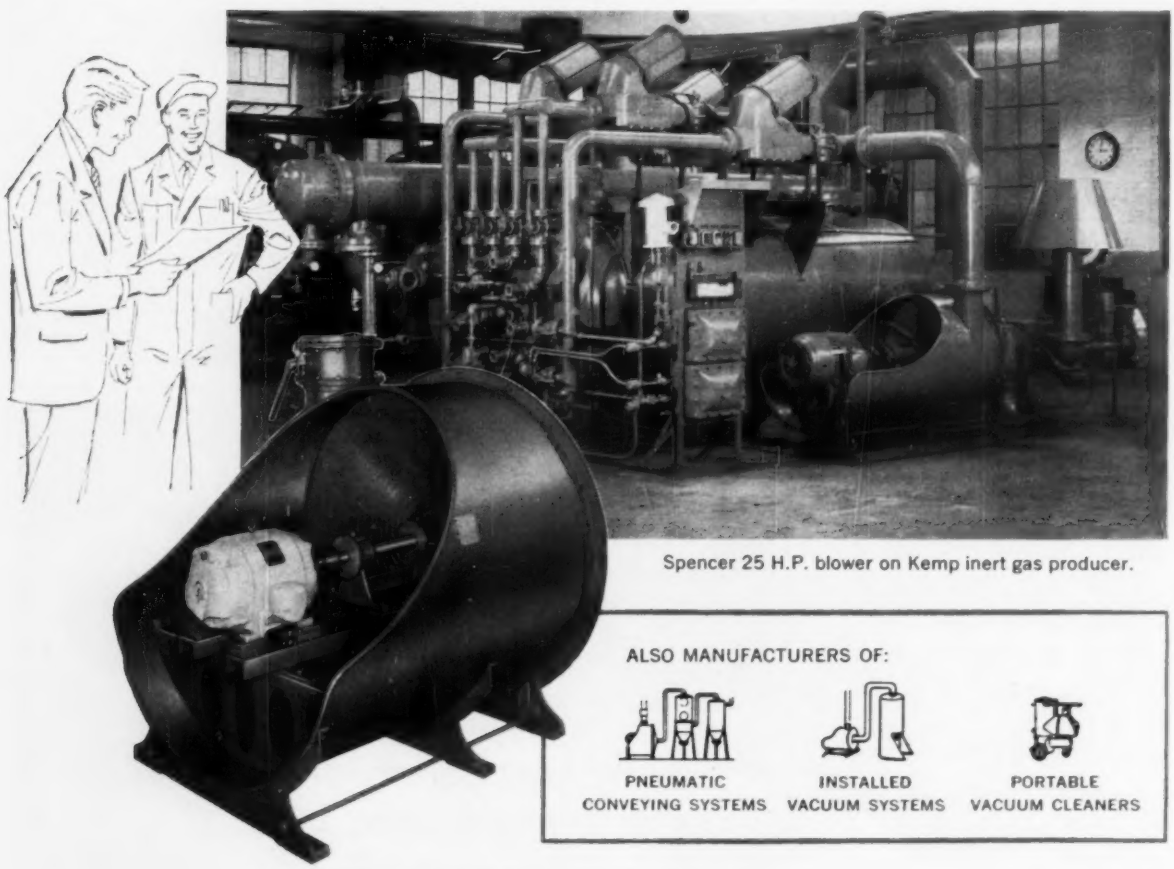
Reliable SPENCER Blowers

Another one of many critical applications where SPENCER blowers are preferred because of their:

NON-CONTAMINATION FEATURE—Delivery of clean air is assured. Absence of any internal lubrication (all bearings are outside of casing) means air cannot become contaminated.

COMPLETE DEPENDABILITY—Simplicity of design (lightweight impellers the only moving parts) and ruggedness of construction greatly lessen likelihood of service being needed. Proven performance promises uninterrupted service . . . thousands of Spencer blowers have been in operation for many years with no maintenance or repair required.

COMPACTNESS—Solidly constructed . . . with no unnecessary bulk.



Spencer 25 H.P. blower on Kemp inert gas producer.

ALSO MANUFACTURERS OF:

PNEUMATIC CONVEYING SYSTEMS

INSTALLED VACUUM SYSTEMS

PORTABLE VACUUM CLEANERS

Request Catalog #126B containing complete specifications on Spencer blowers, available in standard capacities of:

⅓ to 1,000 H.P.
Up to 20,000 C.F.M.
4 oz. to 10 lbs. pressure

The SPENCER TURBINE COMPANY
HARTFORD 6, CONNECTICUT

Circle 2444 on Page 48-B

partment. Information available from *Pangborn Corp.*

2284. Burnishing Compound

Oakite Products, Inc. will send information on a compound "Oakite FM 286" designed for burnishing zinc, aluminum, steel, and other metals.

Welding and Joining Equipment

2285. Welding Design

Lincoln Electric Co. publishes a series of articles on "Weldesign"—ideas, guides, data, and nomographs for efficient welding design. Folder 1204.1 features "Design of Welded Rolls."

2286. Brazing Manual

24-p. manual contains data on brazing shapes, castings, tubing, and assemblies made of aluminum, cast iron, copper, brass, and steel. *All-State Welding Alloys Co., Inc.*

2287. Arc Welding Equipment

6-p. folder from *Hobart Brothers Co.* illustrates line of automatic and semi-automatic arc welding equipment. Applications for the various processes included.

2288. Welding and Cutting

16-p. catalog on "Torchweld" apparatus discusses welding torches, cutting attachments, tips, economizers, and regulators. *National Cylinder Gas Div.*

2289. Silver Brazing

Bulletin 20 gives the story on silver brazing and its benefits, including details on alloys, heating methods, joint design and production techniques. *Handy & Harmon.*

2290. Welding Stainless

Air Reduction Sales Co. will send "Electrode Pocket Guide" and "Welding Wire Pocket Guide".

2291. Power Supplies

The *Glenn Pacific Power Supply Corp.* has published literature and specifications on variable-slope, constant voltage power supplies.

2292. Welding Electrode Chart

A 23 x 25 in. wall chart gives description, number, color code, mechanical properties, size, current range, procedure and application data on line of *Hobart Bros.* arc-welding electrodes.

2293. Chromallizing

4-p. bulletin 501 presents the benefits of chromallizing — a metal diffusion process — for high-temperature applications. *Chromalloy Corp.*

2294. Welding and Brazing

56-p. catalog and instruction manual covers welding, brazing, soldering and fluxes. Properties, uses and application data included. *All-State Welding Alloys.*

2295. Resistance Welders

12-p. brochure illustrates line of resistance welders — spot, projection, seam, roll-seam, portable welders, aircraft spot and seam, flash, multi-spot and automatic machines. *Federal Machine and Welder.*

2296. Welding Guide

80-p. "Vest Pocket Guide to Better Welds" published by *Hobart Brothers Co.*, gives data on proper welding procedures and techniques, causes and cures of welding troubles, welding symbols, electrodes, definitions, joints, wires and fluxes, and power sources.

Inspection and Control Equipment

2297. Ultrasonic Inspection

Is fast and accurate with the "Sonoray 5" and plug-in "Sonogate" flaw alarm and red signal light. In scanning large areas, the inspector looks at screen only when signal announces a flaw larger than critical size. *Branson Instruments.*

2298. Camera Microscopes

Microscope Catalog 2-I discusses metallographs, universal camera microscopes and auxiliary attachments. *Unitron Instrument Co.*

2299. Internal Inspection

"Borescope Catalog" discusses instruments for internal inspection. Point of entry requirement is 0.10 in. *National Electric Instrument Div.*

2300. Scientific Apparatus

Scientific Products has published a 40-p. brochure entitled "S/P Review" (equipment and supply issue). A complete listing of major laboratory equipment and supplies is included.

2301. Micro-Metallograph

E. Lietz, Inc. will send information on their Micro-metallograph "Model MM" with inverted microscope stand and mechanical stage; coarse and fine focusing.

2302. Portable Brinell Tester

The *King Tester Corp.* publishes literature describing a portable hardness tester for evaluating any size, shape or thickness of metal. Loads from 62½ kg. to 3000 kg.

2303. Eddy Current Inspection

Bulletin IM-1000 from *Budd Instruments Div.* contains information on a multiple-frequency eddy current inspection unit. Test frequencies range from 1 kilocycle to 4 megacycles.

2304. Research Metallograph

Bausch & Lomb will send Catalog E-240 describing complete line of metallographic equipment as well as their research metallograph.

2305. Sulphur Analysis

16-p. catalog describes sulphur and carbon determinators and complete line of accessory equipment and supplies. *Harry W. Dietert Co.*

2306. Mass Spectrometer

Bulletin CEC1843-X1 describes "Model 21-611" mass spectrometer — small, portable, excellent for special projects or for adaptation to residual-gas analysis. *Consolidated Electrodynamics Corp.*

2307. Proving Rings

Steel City Testing Machines Inc. has published literature describing proving rings to measure any load, compression or tension.

2308. Gas Analyzer

Booklet discusses furnace atmosphere analyzer which automatically records volume percent of four gases — O_2, CO, CO_2 and CH_4. *Perkin-Elmer Corp.*

2309. Universal Tester

Literature from *Riehle Testing Machines* describes universal tester which has maximum versatility for research and control operations.

2310. Emission Gage

General Electric Co., has published information on an X-ray emission gage which performs continuous analysis on solids, liquids, liquid mixtures, slurries, powders, and rod and wire during actual production.

2311. Metallographic Equipment

The American Optical Co. has published information on picture-in-a-minute photomicrography with their "Workhorse" metallographs and accessories.

2312. Spectrum Analyzers

Raytheon Co. will send brochure describing "Rayspan" spectrum analyzers. Complete analysis at rates as high as 200

NOTHING heats like...
is more modern than...
is more economical than... GAS
NO BLOWER OR POWER NEEDED
BUZZER
REG. U.S. PAT. OFFICE
JUST CONNECT TO GAS SUPPLY
INDUSTRIAL GAS
BURNERS & FURNACES
Using Only Low Pressure Gas
for Clean, Fast, Quiet Heat-Up at Lowest Cost!
HIGH SPEED FULL MUFFLE FURNACES
Bench type for heat treating high speed and alloy steels. Temperatures to 2400° F.
LARGE FLOOR TYPE OVEN FURNACES
For universal heat treating of larger pieces. Temperatures to 2000° F.
Write today for complete "BUZZER" CATALOG
Est. 1911
CHARLES A. HONES, INC.
123 So. Grand Avenue, Baldwin, L.I., New York • BAldwin 3-1110
"BUZZER" Burners & Furnaces for Heat Treating, Melting, Soldering
Circle 2445 on Page 48-B

A CONTROL SYSTEM with ORIGINALITY and RELIABILITY

"A major breakthrough in temperature control"

SATURABLE POWER REACTOR CONTROL
AND *Range-Lock PROTECTION
MECHANICAL CONVECTION OVENS
GUARANTEED TO OUTPERFORM ALL OTHERS IN RELIABILITY, SAFETY, AND CONTROL ACTION.

POWER-O-MATIC
THE NEW STANDARD OF PERFORMANCE

*Range-Lock FOOL-SAFE PROTECTION AGAINST OVERHEATING

-POWER-O-MATIC-GO COMPLETELY STEPLESS REGULATION OF TEMPERATURE. SWITCHLESS. INFINITELY PROPORTIONAL. FULLY AUTOMATIC.

-POWER-O-MATIC-GO NO AUXILIARY ELEMENTS OR SWITCHES. NO ELECTRONIC AMPLIFIERS OR TUBES. NO PHOTO CELLS. NO TIMING DEVICES. NO MERCURY OR MECHANICAL RELAYS OR SWITCHES TO ARC.

NO MOVING PARTS
RELIABILITY and EFFICIENCY
BETTER PRODUCTS THRU VISION AND SKILL

2 RANGES 356°F. and 650°F.

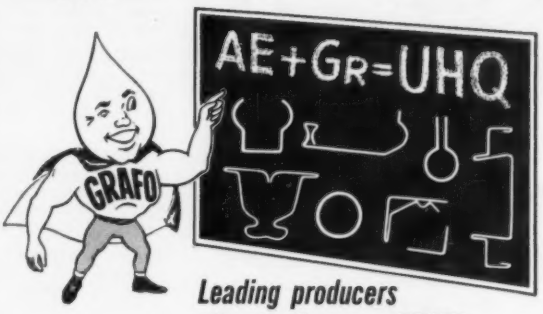
Write for free Bulletin 1960

ECONOMICAL
COMPETITIVELY PRICED
with ovens utilizing standard ON-OFF cycling type control systems.

BLUE M *Electric Company*
138th and Chatham Sts., Blue Island, Illinois
BRANCH: Blue M Engineering Co., 2312 So. Main Street, Los Angeles 7, California

Circle 2478 on Page 48-B

Happy answer to a problem!



Leading producers of extrusions use GRAFO

Many manufacturers of aluminum extrusions already know the basic answer. It's simply this: *Aluminum Extruding* plus *GRAFO* equals *Uniformly High Quality!*

Why? Because GRAFO Colloidal Graphite dispersed in water reduces die wear, prevents sticking, gives better metal flow and improved production. *Send for booklet "The Biggest Ounce of Protection"*

•If you have a problem of excessive temperatures, pressures or abrasion, let us help you solve it with a GRAFO Water, Oil or Alcohol Dispersion for your conditions.

GRAFO COLLOIDS *Corporation*
279 Wilkes Place, Sharon, Pa.

Circle 2479 on Page 48-B

For that SUDDEN SERVICE on —

Tool Steels to Fit Every Tool Steel Purpose

Call your nearest ZIV warehouse. Ample stocks, prompt efficient service on every order, large or small, from full bar lengths or pieces cut to any length.

Tool Steel—Bar Stock, Forgings and Castings
Oil Hard—Water Hard—Air Hard—Hot Work—Shock
Plastic Mold—Graphitic—Hollow Bar
High Speed Bars and Tool Bits—Drill Rod
Flat Ground Stock (Oil-air-Mild Steel)

FREE LITERATURE AND EXPERT PERSONAL ATTENTION UPON REQUEST.
CALL OR WRITE YOUR NEAREST WAREHOUSE.
ESTABLISHED 1911

ZIV STEEL & WIRE CO.

High Grade Tool Steel

ZIVCO TRADE MARK

BUTLER, WIS. DETROIT, MICH. EAGLE RIVER, MICH.
INDIANAPOLIS, IND. ST. LOUIS, MO. TOLEDO, O.
2945 W. HARRISON STREET — CHICAGO 12, ILL.

Circle 2480 on Page 48-B

ACCURATE
DEPENDABLE
LOW COST

HEAT TREATING
with
YOUNG BROTHERS OVENS

designed and built for individual product and process requirements

batch and conveyor types up to 1000° F

Write for Bulletin 157

YOUNG BROTHERS CO.
1829 Columbus Road • Cleveland 13, Ohio
Over 60 years of service

Circle 2481 on Page 48-B

times per sec. with resolutions less than 3% of band.

2313. Information Searching

Brochure discusses documentation service which delivers the world's current metallurgical literature to you every two weeks in digest form. *American Society for Metals.*

2314. Metallographic Polisher

Buehler Ltd. will send details on "Polimet" metallographic polishers with variable speed (100 to 1200 rpm.), quiet and vibration-free operation, and high torque (up to ½ h.p.).

2315. Thickness Gage

Folder describes the "Elcotector", a micro-gage and comparator which measures metallic and nonmetallic coatings on metallic bases, and metallic coatings on nonmetallic bases. *Ferro Corp.*

2316. Specimen Mounting Material

The *Fulton Metallurgical Products Corp.* has published a brochure describing "Quickmount", a fast-setting, self-curing specimen mounting material that produces clear mounts without application of heat or pressure.

2317. Gaging Coatings on Steel

A brochure from *Twin City Testing Corp.* includes a description of various nondestructive methods employed for measuring the thickness of organic and non-magnetic coatings on iron and steel.

2318. Metallograph for Research

The *Ercona Corp.* will send descriptive literature on their metallograph, "Neophot", an optical testing instrument which is adaptable to the research requirements of modern industry.

2319. Stainless Laboratory Ware

Harshaw Scientific Div. will send an 8-p. illustrated booklet describing more than 125 items of stainless steel laboratory ware.

2320. Vacuum Spectrometer

Radio Corp. of America will send details on their X-ray vacuum spectrometer, for analysis of the lighter elements.

2321. Superficial Hardness Tester

Catalog RT-58 gives complete information on line of Rockwell hardness testers and includes data on the superficial tester. *Wilson Mechanical Instrument Div.*

Production and Casting Equipment

2322. Hydrogen Generator

The Electric Furnace Co. will send bulletin No. 602 on a hydrogen gas producer which uses commercial anhydrous ammonia.

2323. High-Vacuum Furnaces

The "NRC Vacuum Micronicle" contains details on vacuum levitation furnace and other news concerning products made better with high-vacuum equipment. *NRC Equipment Corp.*

2326. Selective Plating

Production and repair plating without using immersion tanks enables you to (a) precision-plate selected areas economically without disassembling components, and (b) deposit metal rapidly where ordinary electroplating is difficult. *Sifco Metachemical, Inc.*

2328. Vacuum Pumps

Bulletin 8-15 discusses vibrationless, mechanical vacuum pumps capable of producing vacuums down to 2×10^{-6} mm. Hg. *Consolidated Vacuum Corp.*

2329. Alloy Cast Iron

8-p. folder from *Centrifugally Cast Products Div.* charts the engineering properties of Meehanite metal, "Ni-Resist" iron, Ni-Resist ductile iron, and ductile iron.

DURALOY
DURASPUN
RADIANT
BURNER
TUBE
ASSEMBLY
HERE WE HAVE A COMBINATION OF
1...statically cast bends and reducers
2...centrifugally cast tubes
3...machining
4...welding
This is indicative of the high alloy casting work we turn out at Scottdale. We can produce static castings up to 6 tons and centrifugal castings up to 24 inches in diameter (OD) and up to 15 feet in length (depending upon the diameter). We have excellent machining facilities and men skilled in the welding of the chrome-nickel alloys.
Our metallurgists will be glad to recommend the proper alloy for the casting you need to combat corrosion, high temperature or abrasion or any combination of these three.
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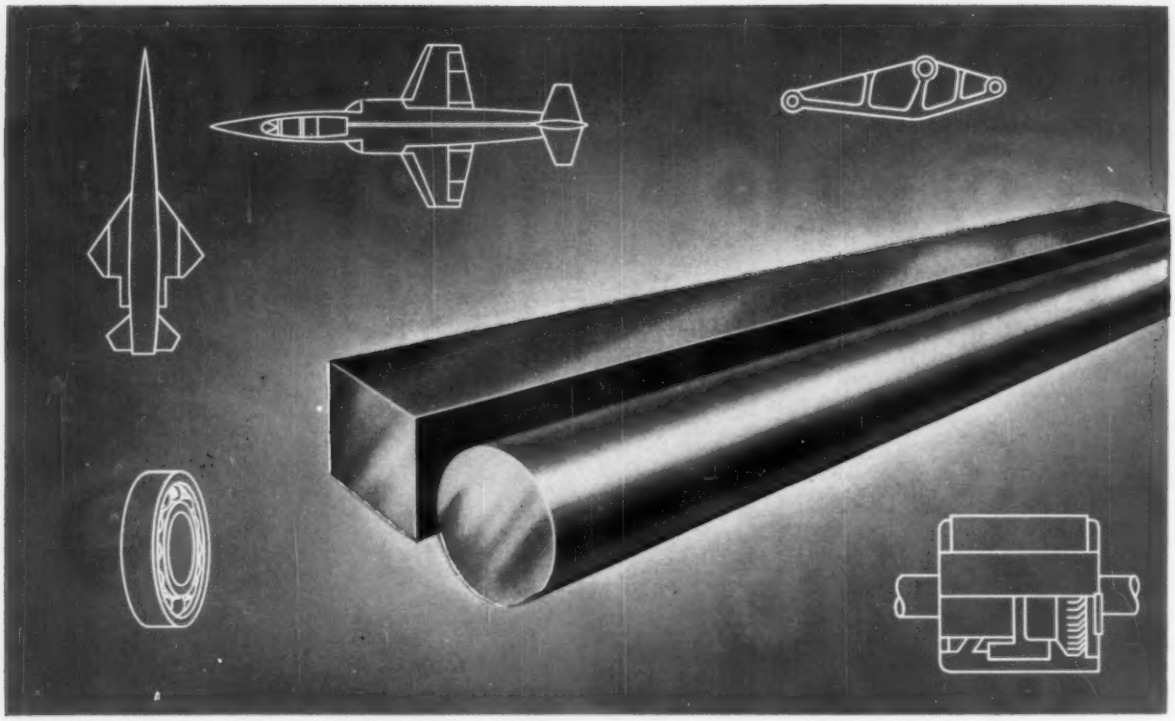
EASTERN OFFICE: 12 East 41st Street, New York 17, N. Y.
CHICAGO OFFICE: 332 South Michigan Avenue
DETROIT OFFICE: 23906 Woodward Avenue, Pleasant Ridge, Mich.

Circle 2447 on Page 48-B



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. . . for applications requiring high ductility and tensile strength up to 285,000 psi.

Compare these data . . .

TRANSVERSE TENSILE PROPERTIES 8" square billet of VAC-ARC DYNAFLEX		
Property	*Mid-Radius*	*Center Area*
Tensile Strength (psi)	287,000	285,000
Yield Strength .2% (psi)	252,500	250,000
Elongation %	8	8
Reduction of Area %	25	24

Literature available on all Vac-Arc grades upon request . . . Send today!

Where design demands uniform high strength, toughness and ductility at both low and elevated temperatures, Vac-Arc Steels more than meet the requirements. These steels—produced by Latrobe's consumable electrode vacuum melting process—possess superior cleanliness, lower gas content, improved ingot structure and desirable longitudinal and transverse mechanical properties.

The following grades of Latrobe's Vac-Arc steels are available in a range of sizes and shapes: Pandex (Type A-286) for high temperature applications; MV-1 (Type M-50) and Regent (Type 52100) for critical bearing design; Dynaflex (Type H-11) for aircraft and missile components; AGT (SAE 9310) for carburized aircraft gears.

Many grades of Vac-Arc steels are being produced to meet particular application requirements. Send us your specifications or call your nearest Latrobe representative for *experienced* technical assistance.

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Circle 2448 on Page 48-B

2330. Induction Melting

"Tocco" induction heating furnaces will melt bronze, aluminum, and stainless steel for high-quality nonporous castings. *Ohio Crankshaft Co.*

2331. Ferrovanadium Additions

Ferrovanadium additions to cast irons promote the formation of small, uniform graphite flakes thus increasing tensile strength. *Vanadium Corp. of America* will send literature.

2332. Vacuum Coating Service

4-p. brochure has been issued by *Poly-Kote, Inc.* on a custom vacuum coating service for functional and unusual decorative purposes.

2333. Refractories and Mortar

8-p. publication outlines characteristics and applications for brick and mortar in aluminum melting furnaces. *Kaiser Refractories & Chemicals Div.*

2334. Quality Control of Castings

The *Lebanon Steel Foundry* has published a bulletin on magnetic particle inspection of steel castings which discusses the various processes, equipment and facilities available.

2335. Vacuum Button Furnace

The *Zak Machine Works, Inc.* will send literature on their button furnace, as well as information on their facilities and other products.

2336. Insulating Firebrick

Catalog R-2-H from the *Babcock & Wilcox Co.* tells about lightweight insulating firebrick with lower thermal conductivity.

2337. Carbon Brick

The *National Carbon Co.* will send details on "Grade NMA" carbon brick for blast furnace linings. Low permeability . . . high thermal conductivity . . . dimensional stability at high temperature.

2338. Electrode Properties

Data sheets from *Great Lakes Carbon Corp.* cover chemical and physical properties of graphite electrodes — in various grades and sizes.

2339. Silicone Mold Washes

The *General Electric Co.* will send information on two new silicone materials for use as washes for ingot molds in the steel industry.

2340. Monolithic Refractory Wall

Information from *Refractory & Insulation Corp.* on "Furnace Blok", a method of building monolithic refractory walls and arches without the use of wooden forms.

Parts, Forms, Shapes

2342. Pressure Tubing

Bulletin TB-417 from *Babcock & Wilcox Co.* gives data on job-matched seamless pressure tubing made of carbon or alloy steel.

2344. Tubing for Aerospace

12-p. Bulletin 372 published by *Superior Tube Co.* presents information on tubing for aircraft, missiles and rockets.

2345. Metal-Mesh Belts

130-p. reference manual contains information on metal-mesh belts for continuous production operations. *Cambridge Wire Cloth Co.*

2346. Spring Products

The *Associated Spring Corp.* publishes a periodical, "The Mainspring." The June-July 1960 issue includes an article "The ABC's of Spring Reliability."

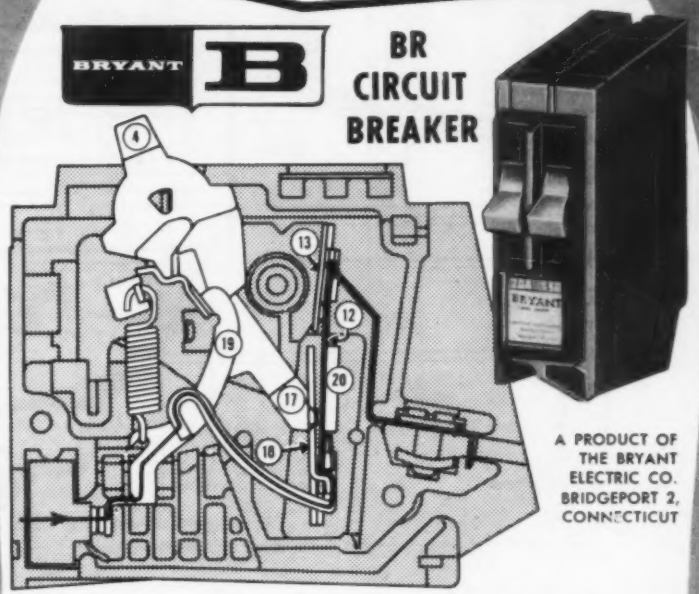
2347. Diesel Fuel Injection Tubing

Superior Tube Co. has Data Memorandum No. 10 on diesel fuel injection tubing; working pressures from 3000 to 9000 psi.

Chace Thermostatic Bimetal

ACTUATES ANOTHER PRECISION PRODUCT

BRYANT B BR CIRCUIT BREAKER



A PRODUCT OF THE BRYANT ELECTRIC CO. BRIDGEPORT 2, CONNECTICUT

Interchangeability, compactness and sturdiness are three features readily apparent in Bryant's BR Circuit Breaker. The ***mounting dimensions*** make it interchangeable with five other makes; there are ***two*** breakers in the space formerly used for one; the mechanism is supported and enclosed by a husky ***metal frame*** and is completely independent of the insulating case.

Not so readily apparent is the "heart" of the BR Breaker. The all-important thermal-magnetic "nerve center" includes:

Time-delay controlled by the load bimetal (12) for overload protection . . . ***overload bends free end of bimetal to right disengaging trigger (17) from armature (18) causing contact arm (19) to open.***

Second bimetal (13) of the "force balance" type, providing enclosure — ***ambient — compensation . . . as load bimetal (12) bends to right with rising ambient temperature, compensating bimetal (13) bends left, removing pressure from (12).***

Magnet (20) reacts instantly by releasing trigger (17) at about 1000% rating to limit fault current damage.

The load bimetal and the compensating bimetal are made of dependable Chace Thermostatic Bimetal. This dependability is born of two most important factors: 1. Uniformity that comes from the manufacture of precision bimetal, ***always made to specifications.*** 2. Experience. Chace has specialized in one product—***and one product only***—for more than a third of a century. Manufacturers' valuable names are safe on the outside with Chace Thermostatic Bimetal on the inside of their products.

SEND NOW FOR OUR NEW "INFORMATION BOOKLET!" It contains many well illustrated pages of general information and examples of successful applications of bimetal. 36 types of Chace Thermostatic Bimetal are available in coils, strips and completely fabricated elements of your design.

IT BENDS WITH THE HEAT

W. M. CHACE CO.
Thermostatic Bimetal
1926 BEARD AVE., DETROIT 9, MICH.

Circle 2449 on Page 48-S

FOR A NEW CONCEPT OF QUALITY SPECIFY

B&W *Job-Matched Lectrosonic heat exchanger tubes*

B&W offers you:

- an electric-resistance-welded carbon steel heat exchanger tube manufactured under a rigid system of continuous quality control — and backed by five years of extensive field service
- a dimensionally accurate, uniform tube that fits properly into tube sheets and threads easily through baffles
- a tube with a new concept of quality designed specifically for economical long life in heat exchangers

B&W Job-Matched LECTROSONIC Heat Exchanger Tubes are available through a nationwide network of district sales offices and steel service centers. And remember — matching tubes to jobs assures you the *right tube,* in the *right quantity,* at the *right time.* For more information call your local B&W District Sales Office, or write for Bulletin TB-431. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pennsylvania.

B&W

THE BABCOCK & WILCOX COMPANY

TUBULAR PRODUCTS DIVISION

TA-9057-WP 1

Seamless and welded tubular products, solid extrusions, seamless welding fittings and forged steel flanges—in carbon, alloy and stainless steels and special metals

Circle 2450 on Page 48-B

The American Society for Metals and Metal Progress serve 32,000 member-readers in 11 major areas of the metals industry.

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS: Alloy, Carbon, Free Machining, Stainless Steels, Hot and Cold Finished Bars.

NONFERROUS METALS: Aluminum, Beryllium, Brass, Bronze, Columbium, Copper, Lead, Magnesium, Molybdenum, Monel, Nickel, Rare Earths, Tantalum, Titanium, Tungsten, Zinc, Zirconium.

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS: Special Alloys; Carbon, Graphite; Ceramics, Cermets, Thermal Insulating and Special Electrical Materials.

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT: Metallic and Non Metallic Reactor Materials, Fuel Elements, Pressure Vessels, Control Elements, Related Equipment.

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT: Abrasives; Carbides; Coolants, Oils and Lubricants; Arc and Gas Cutting Equipment, Saws; Forging, Pressing, Extruding, Chemical Milling, Slitting, Straightening, Spinning and Explosive Forming Equipment; Tool and Die Steels, Plastic and Other Short-Run Die Materials.

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES: Atmosphere Generators and Gases; Commercial Services; Furnaces; Controls, Indicators and Recorders; Induction, Flame and Salt Bath Equipment; Ovens; Cryogenic Equipment; Pyrometers; Quenches; Samplers and Analyzers; Trays, Refractory Parts.

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES: Alkaline Cleaning, Pickling, Degreasing, Descaling, Buffing, Polishing, Blasting, Plating; Porcelain Enameling, Purifying; Painting Equipment and Supplies; Rust Preventives; Abrasives.

WELDING AND JOINING EQUIPMENT AND SUPPLIES: Gas, Resistance and Arc Welding Equipment and Supplies; Electrodes; Adhesives, Fasteners; Hard Surfacing, Brazing and Soldering Equipment and Supplies.

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES: Microscopes and Attachments; Analytical and Mechanical Equipment; Gages, Comparators, Hardness Testers, Nondestructive, Electronic and Other Scientific Inspection Equipment.

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES: Electric and Vacuum Furnaces and Equipment; Refractories; Ferro Alloys; Foundry Irons and Coke; Rare Earths; Alloying and Refining Agents; Annealing, Soaking and Sintering Furnaces; Rolling Equipment; Industrial Gases; Foundry Equipment and Supplies.

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS: Castings (Malleable, Gray Iron, Steel, Nonferrous), Forgings, Extrusions, Powder Metal Parts, Springs, Stampings, Tubing, Weldments, Wire.

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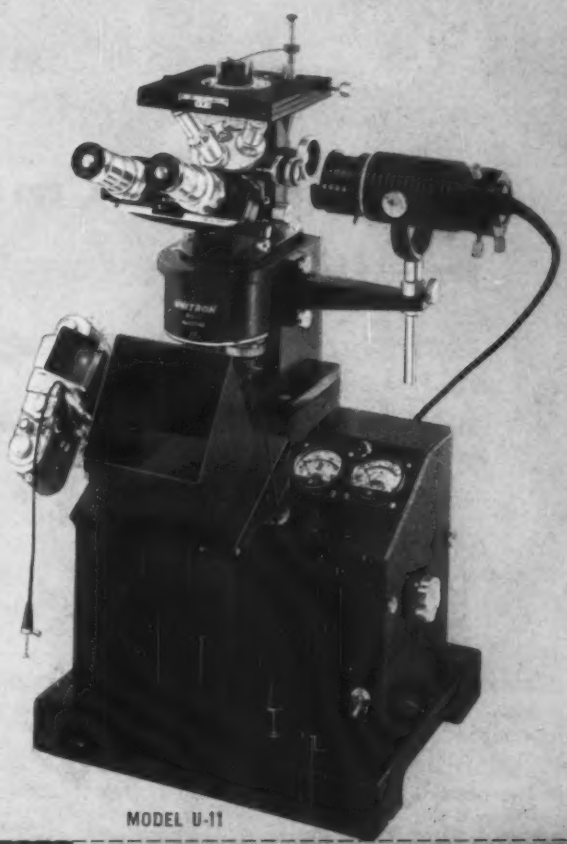
MODEL MEC

UNITRON INVERTED Metallurgical Microscope: This compact unit provides many of the features usually found only in larger metallographs. Standard equipment includes optics for 25–1500X, polarizers, filters, transformer in base, etc. A built-in camera attachment for 35mm. photography is included with the binocular and available for the monocular model. Extra accessories include Polaroid camera attachment, vacuum heating stage and illuminator for transmitted light. Think of the time which your laboratory can save by providing each metallurgist with one of these handy, inexpensive units for use at his desk.

Monocular Model MEC $399 Binocular Model BMEC $615

UNITRON METALLOGRAPH and Universal Camera Microscope: A completely self-contained instrument of modern design for visual observation, photography, projection, and measurement of both opaque and transparent specimens; using bright field, dark field, or polarized illumination. Standard equipment includes all optics for 25–2000X, polarizers, filters, 3¼″ x 4¼″ camera, and many accessories. Also available are camera attachments for Polaroid, 35mm., and motion picture photography; vacuum heating stage for temperatures to 1500° C.; and macro-objectives (5–40X). Even laboratories on a limited budget can enjoy the precision, speed and efficiency possible only with a complete installation of this type.

Monocular Model U-11 $1195 Binocular Model BU-11 $1379



MODEL U-11

There is a free 10 day trial offer on any UNITRON Microscope.

Let the instrument prove it's value to you — in your own laboratory — before you decide to purchase.

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THE TREND IS TO UNITRON

Circle 2353 on Page 48-B

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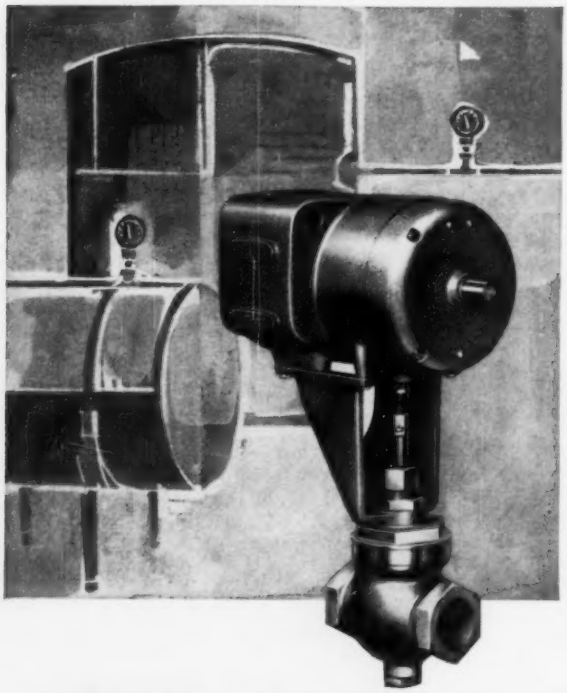

OPERATE ALL INDUSTRIAL TYPE DAMPERS

more torque! more precise positioning for industrial valve and damper applications *New Honeywell*

ACTIONATOR heavy-duty electrical control motors*

Use these compact, powerful new industrial motors in dairies, breweries, water works—for ovens and cooling towers—wherever highly accurate modulating or two-position control is required.

Some models operate vertical-acting stem valves having lifts of from ½ to 1½ inches. The double-ended shaft can also simultaneously operate rotary stem valves, butterfly valves and other devices through suitable linkages. Other models operate rotary-shaft type valves, dampers, louvers and other final control elements.

ACTIONATOR control motors are available with two-position, floating or proportional control, and with a variety of speeds from 7.4 to 120 seconds full-stroke operation. Torque ratings range to 200 inch/lbs.

Additional features include built-in linkage and strain relief, a mounting yoke and enclosed terminals with gasketed housing to meet JIC specifications. Also available are models that include cam-operated internally mounted switches for a variety of sequencing switching purposes.

For complete information, call your local Honeywell office. Or write Minneapolis-Honeywell, Dept. MP-12-54, Minneapolis 8, Minnesota. In Canada, Honeywell Controls Limited, Toronto 17, Ontario.

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Honeywell

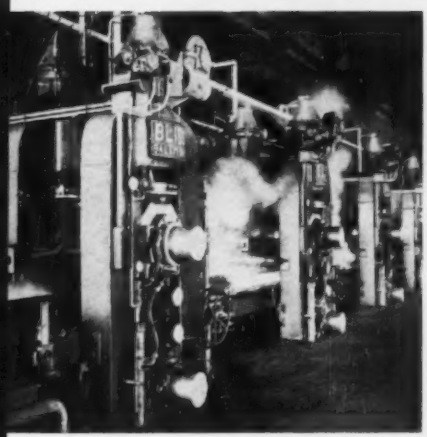
H HONEYWELL — *First in Control* SINCE 1885

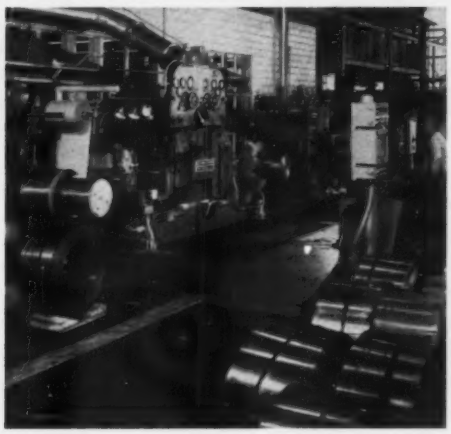
See us in Sweet's 1960 Product Design File, Section 5b-Min.

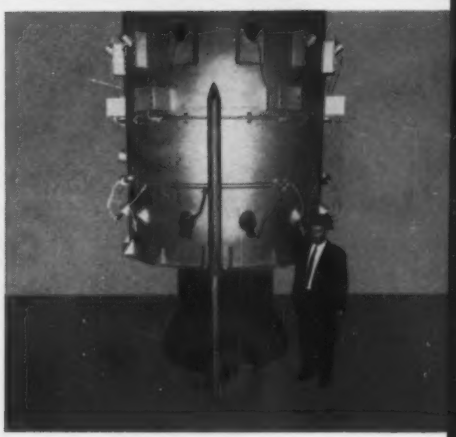
Circle 2354 on Page 48-B

CUSTOM ROLLING

of your special metals—the way you want it done!







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These and other special metals find ready handling ability at Superior Steel—precisely to your requirements! Modern hot and cold rolling mills, vacuum and controlled atmosphere continuous annealing furnaces, highly-skilled operating personnel are all coordinated by close metallurgical supervision of each order in process. • The special experience gained in conversion of difficult metals over many years is your assurance of satisfaction when you send your problems to Superior. Let us consult with you!

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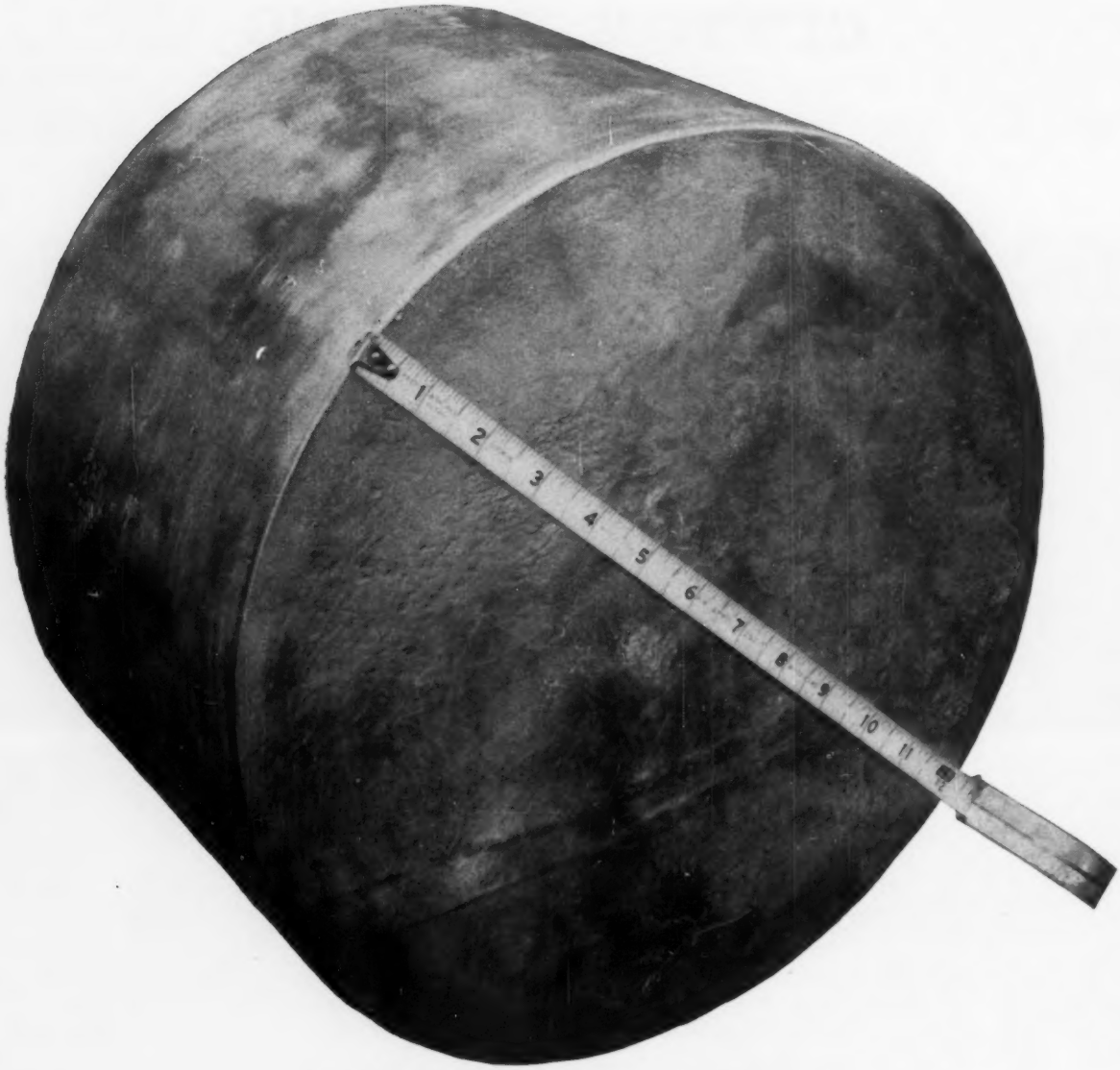
Circle 2355 on Page 48-B



SINTERED MOLY FORGING BILLET WITH ONE-FOOT DIAMETER

NOW...ONE FOOT DIAMETER MOLYBDENUM!

Now you can get General Electric molybdenum in diameters up to one foot! This is another first—from General Electric, of course—in PS (for pressed and sintered) moly.

Large size squares, rectangles, slabs and hollow or solid preforms made from this pure refractory metal are available, too. (Maximum cross sectional dimensions are those that can be inscribed in a 12-inch circle. Maximum length—30 inches.)

PS materials are versatile. They can be worked, melted or machined! Whether you forge, vacuum arc melt with consumable electrodes, or need to machine a product directly from a billet, tube or preform, there's a General Electric PS Moly product that can be engineered for you.

Need high purity? General Electric PS metal products are produced from pure metal powders, prepared by hydrogen reduction, cold pressed hydrostatically into basic products and sintered in a high temperature hydrogen atmosphere furnace to gain the density and strength desired. Product purity and uniformity are emphasized throughout this manufacturing process.

Want more information? Write General Electric Co., Lamp Metals and Components Dept., 21800 Tungsten Road, Cleveland 17, Ohio.

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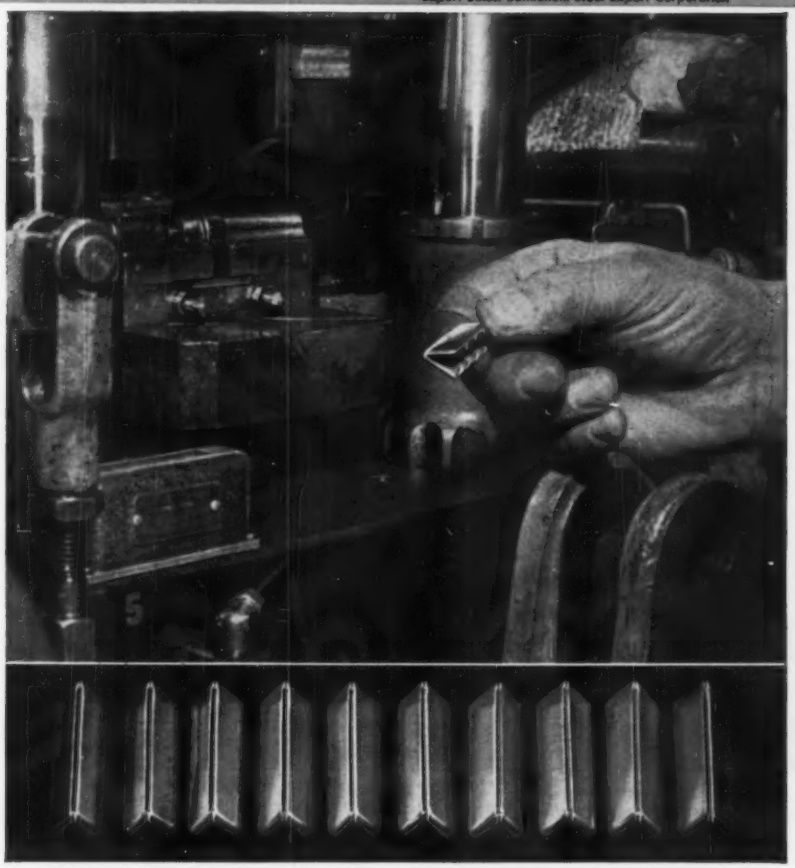
GENERAL ELECTRIC

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Sales: Bethlehem Steel Export Corporation



Lehigh H blanks and forms 1,000,000 pieces before redressing is necessary

Using a die of Bethlehem Lehigh H tool steel, Sobel Metal Products Co., Easton, Pa., produced this nickel-silver belt accessory, of the type used with army uniforms, at the rate of about 1,000,000 pieces before redressing was necessary. Blanking and forming .020-in. metal, the die was hardened to Rockwell C60-61. One of the requirements of the order was that no marking was permitted on the finished part.

Lehigh H (AISI D-2) is excellent tool steel for jobs like this. Not only is it the leader in machinability among the high-carbon, high-chromium tool steels sold today — it also has improved wear-resistance because its vanadium content has been increased to 1 pct.

As the result of a new manufacturing process, Lehigh H has improved carbide distribution and increased center density. It also has minimum distortion during heat-treatment.

If you want unexcelled machinability, excellent wear-resistance, and plenty of dependability, Lehigh H is your answer. See your Bethlehem tool steel distributor for prompt delivery.

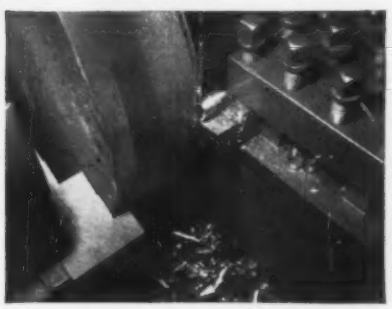
BETHLEHEM TOOL STEEL ENGINEER SAYS:

Blind Holes Can Cause Plenty of Trouble

Unless one uses great care, blind holes can cause a lot of trouble when heat-treating tools. Holes for studs or dowel pins are typical of the blind holes which, as a rule, are paid little attention. Exposing blind holes to liquid quenching produces extremely high internal stresses, which can lead to cracking of the tool, either during heat-treatment or in service.

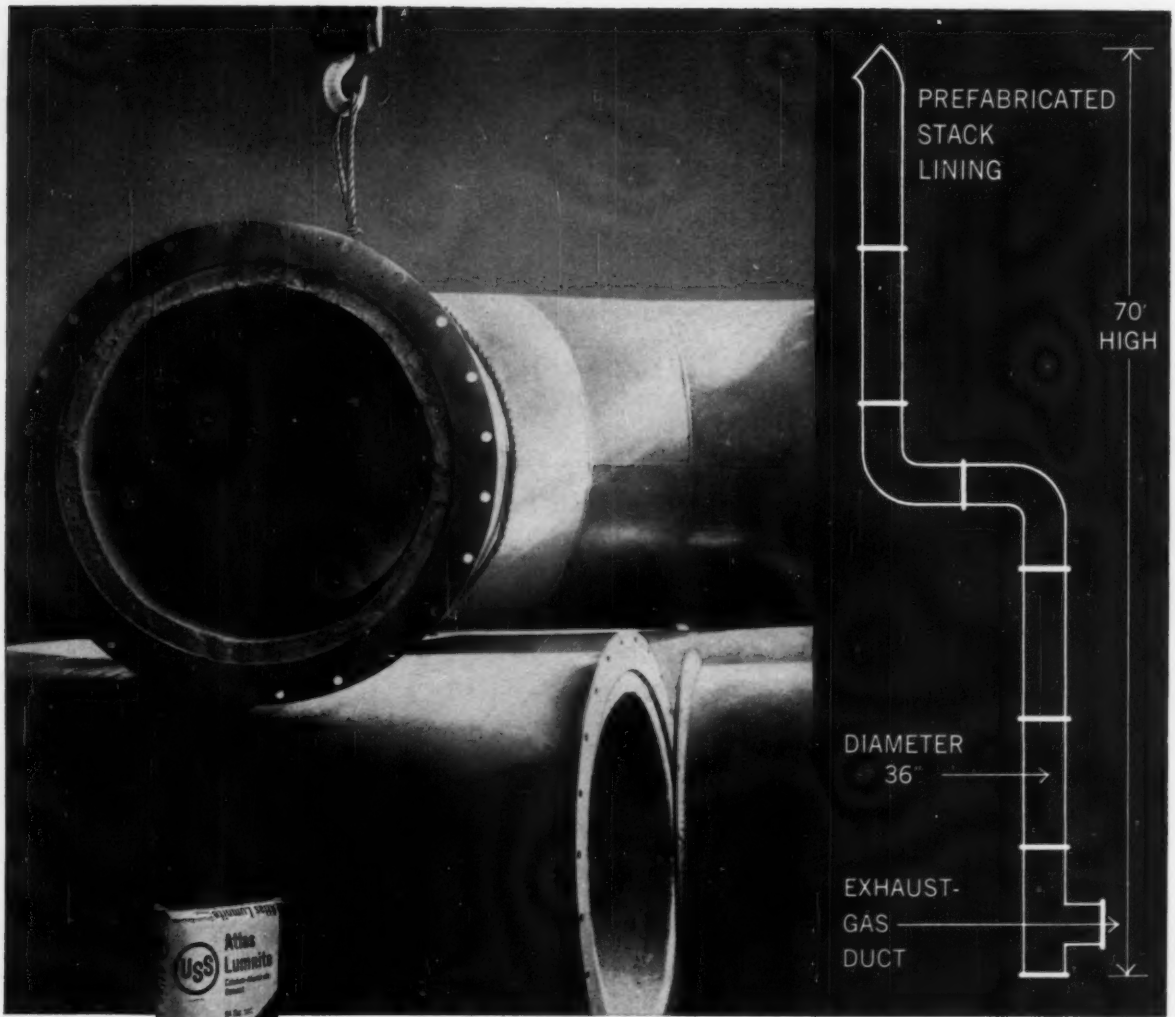
If it is not necessary for blind holes to be hard internally, these difficulties can be avoided by packing the holes prior to the quench, using clay, asbestos rope, steel wool, or a steel plug.

Blind holes are particularly objectionable if they must be uniformly hard on the inside surface. The only way to meet this requirement consistently is to select a grade of air-hardening tool steel.



Be Sure to Try Red Sabre Tool Bits

You're sure of economical cutting when you use Bethlehem Red Sabre Tool Bits, regardless of the type of application. Red Sabre is a super high-speed steel, with about 1.50 carbon, 12.00 tungsten, 5.00 vanadium, and 5.00 cobalt. The bits have high red-hardness and uniform hardness all the way through, for peak resistance to wear and maximum cutting ability. They come hardened to Rockwell C65.



Castable-lined prefab sections of waste-gas ducts and stacks for pit annealers at United States Steel's Homestead (Pa.) Works. **Contractor:** Amsler Morton Company, Pittsburgh, Pa.

Castable lining in prefab stacks reduces costs

When unusual stack and duct layouts are necessary, prefab elbows, tees, dog-legs and straights can be pre-lined with a refractory insulating concrete at considerable savings. Using a castable refractory, bonded with LUMNITE calcium-aluminate cement, monolithic linings can be cast in place without anchors or reinforcing mesh. Since the concrete will reach service strength in 24 hours, early release and re-use of forms are possible, speeding the job. Compared to cutting and fitting small refractory units, there is less material loss. Cluttered job sites and scaffolding are eliminated. And casting indoors means no delays due to weather. Leading manufacturers of refractories offer castables bonded with LUMNITE cement for a variety of installations in metalworking. Castables are packaged mixtures, ready to use. Simply add water, mix and place. For details, write Universal Atlas Cement, 100 Park Avenue, New York 17, N. Y.

L-202

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Universal Atlas Cement
Division of
United States Steel

Offices: Albany · Birmingham · Boston · Chicago · Dayton · Kansas City · Milwaukee · Minneapolis · New York · Philadelphia · Pittsburgh · St. Louis · Waco

Circle 2358 on Page 48-B

big stuff to quality-inspect?

need to radiograph giant castings
for reactor systems?
or weldments on thick-walled
pressure vessels?
or feet-thick solid fuel volumes?
or even heavy lead slabs, maybe?

such jumbo jobs are meat for the massive power (2-3 million volt equivalent) of Picker's Cobalt 60 **Cyclops.** *for instance . . .*

it will find a flaw this small ● in a 10″ thick steel casting . . . the penetrameter will show clearly on the film

(Cyclops users readily produce radiographs that meet and often better the 2% sensitivity requirements of most radiographic inspection codes.)

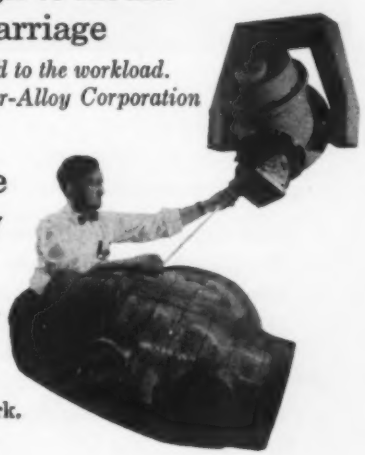
with radiographic power like that, Cyclops makes short shrift of less formidable jobs, too . . .

gets through 5″ of steel in 5 minutes

(And thanks to its unique collimator, secondary radiation is so cut down that radiographs made with Cyclops are characteristically snappy with detail-disclosing contrast.)

Cyclops is compact enough to mount on a go-to-the-job mobile carriage

(Or on a variety of other supports tailored to the workload. Seen here is a jib-mounted unit at Cooper-Alloy Corporation



big surprise is Cyclops low cost

(about one-fourth the price of equivalent energy x-ray equipment)

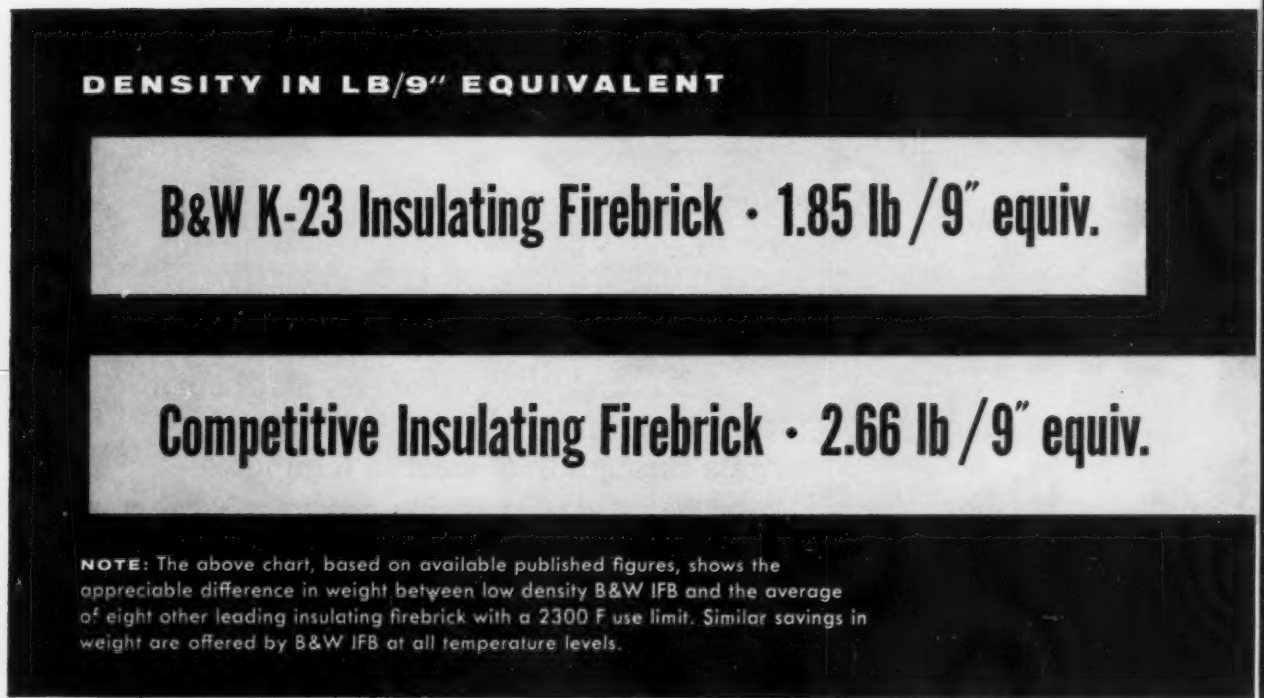
Picker x-ray

There's much more to tell about Cyclops. Get the full story from your local Picker office (see 'phone book) or write Picker X-Ray Corporation, 25 So. Broadway, White Plains, New York.

Circle 2359 on Page 48-B

Another *plus* of Lightweight B&W Insulating Firebrick

LOWER DENSITY means


DENSITY IN LB/9" EQUIVALENT
B&W K-23 Insulating Firebrick · 1.85 lb/9" equiv.
Competitive Insulating Firebrick · 2.66 lb/9" equiv.
NOTE: The above chart, based on available published figures, shows the appreciable difference in weight between low density B&W IFB and the average of eight other leading insulating firebrick with a 2300 F use limit. Similar savings in weight are offered by B&W IFB at all temperature levels.

All insulating firebrick are not the same. Published figures show wide variations in *all* of the important properties among the leading brands of IFB.

Take density. This important property, related to the porosity and the light weight of the brick, affects furnace weight, construction costs, fuel costs, and temperature control. Densities range from a B&W Insulating Firebrick low of 1.85 to a high of 2.80 per 9 inch brick for a competitive Insulating Firebrick—*approximately a 35% difference in dead weight and insulating efficiency.*

You are paying for *insulating* firebrick . . . make sure you get *all* the benefits. B&W—the originator of IFB—manufactures a full line of IFB with an experience-proved balance of light weight, high insulating value, high strength and long life.

For complete information on B&W Insulating Firebrick, write for Catalog R-2-H to The Babcock & Wilcox Company, Refractories Division, 161 East 42nd Street, New York 17, N. Y.

NUMBER 2 OF A SERIES

LESS FURNACE WEIGHT

the payoff

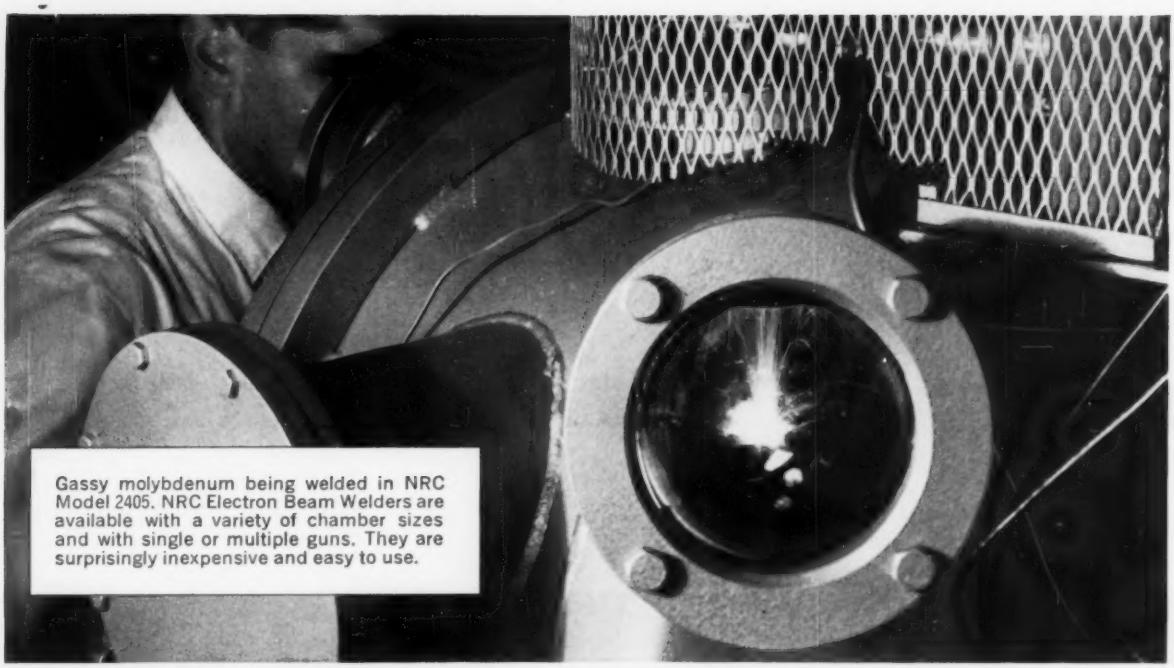
9 TONS LESS WEIGHT to heat and lift in this hood-type, 8 stack annealing furnace. Lined with B&W IFB at 1.85 lb per 9" straight, the refractory lining of this furnace weighs 37,000 lb as compared to 55,200 lb for *average weight competitive IFB*. 33% less weight to heat and lift when you specify B&W IFB. This is just one of many proofs in our files that "there is an important difference in insulating firebrick."

B&W

THE BABCOCK & WILCOX COMPANY

REFRACTORIES DIVISION

Circle 2360 on Page 48-B

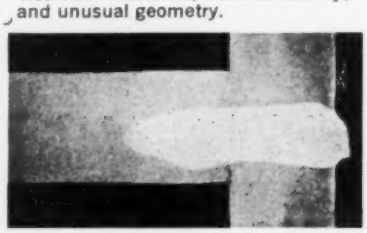


Gassy molybdenum being welded in NRC Model 2405. NRC Electron Beam Welders are available with a variety of chamber sizes and with single or multiple guns. They are surprisingly inexpensive and easy to use.

Can electron beam solve your tough welding problems?

What's So Wonderful About Electron Beam Welding?

Freedom from contamination; Minimum heat affected zone; Unlimited temperatures; Depth/width ratios to 4/1; Precise control of spot size and position; Operation in high vacuum. These advantages are daily solving problems posed by reactive metals, dissimilar materials, heat sensitivity, and unusual geometry.



Typical Solutions

- Inaccessible joints made by "continuous spike weld" (illustrated).
- Seam welded tungsten and tantalum tubes.
- Delicate instruments evacuated and sealed.
- Sintered plate welded without cracking.
- Finish machined parts joined without distortion.
- Precision bead at bottom of 1/16" slot.
- Titanium insert edge-welded to copper sleeve.
- Thin and thick sections joined easily.
- Crackless welding of glass-sealed feed-thru to sleeve.

NRC Small Lot Welding Service Gives Low Cost Answer

Here's a low cost, no risk way to find out if electron beam welding can solve your problems as successfully as it has those of others.

The NRC Small-Lot Welding Service was set up to prove that the Model 2405 Electron Beam Welder can indeed often "weld the unweldable." It gives you the chance to see exactly what the combination of superior equipment and experience can do with your problem welds. And, if you like, you can be your own operator!

The cost? NRC charges only for time and materials. Our prime interest is to help you discover whether electron beam welding is practical for your specific application.

Try The NRC Small-Lot Welding Service

The solution to your problem may be waiting for you right now at NRC Equipment Corporation. The sooner we hear about your application, the sooner we can tell you whether electron beam welding sounds practical, and, if appropriate, add you to our work schedule. Or, send for general information on Electron Beam welding and details on Model 2405, available for early delivery at less than $17,000.00.

NEO-29

NRC
EQUIPMENT CORPORATION

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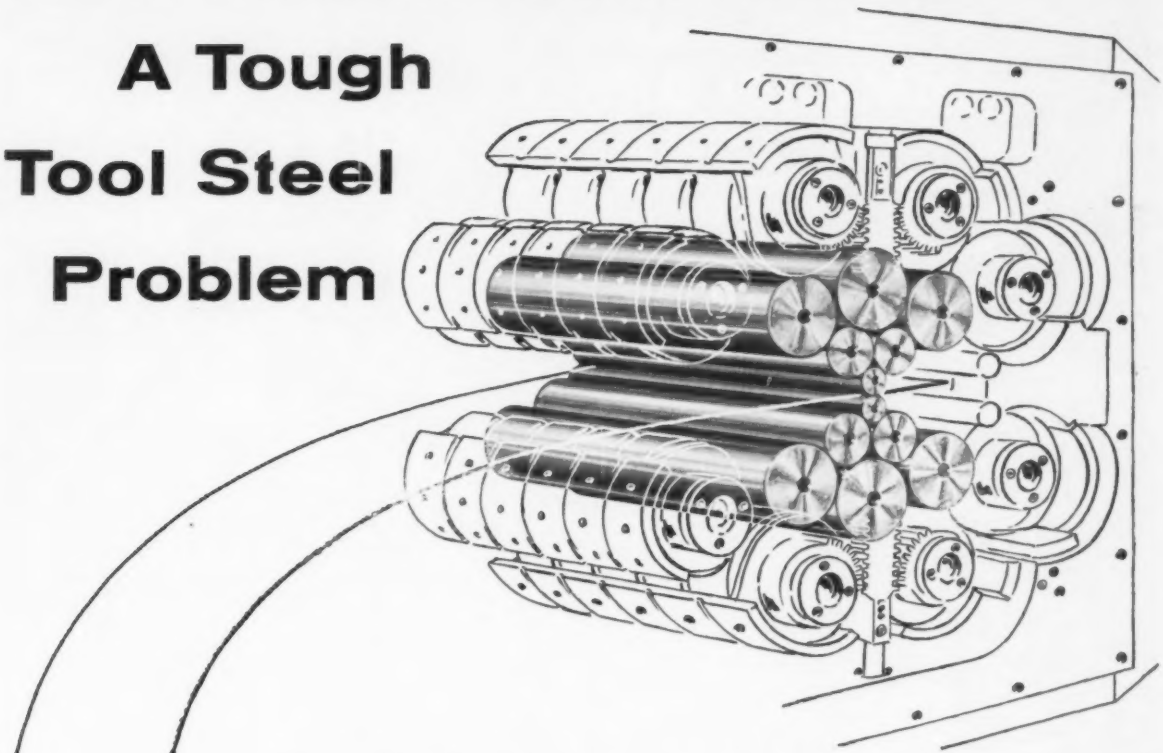
How UDDEHOLM Solved A Tough Tool Steel Problem



Sendzimir Mill Work Rolls, to impart that high finish to cold-rolled material, must, themselves, have an extremely fine surface finish.

The Problem—Produce a "clean" steel for high pressure and high speed cold rolling application.

The Solution—UHB "Tri-Z", a high carbon, high chromium steel with an absolute minimum of non-metallic inclusions.

Uddeholm metallurgists solved the problem by starting with the purest Swedish ores, having very low sulphur and phosphorous content. Then, they used extreme care in refining, a special pouring technique and quality controls to the highest standards. Because of its "cleanness", its ability to take an exceptionally high finish and stand up under high pressure and high rolling speed, "Tri-Z" is the criterion for Sendzimir Mill Rolls.

All Uddeholm Tool Steels, whether for standard or unusual applications, adhere to the same high quality standards. You can choose from more than 2800 combinations of grade, shape, size and finish. Contact your nearest Uddeholm Specialty Steel Service Center—Newington, Conn., New York City, Cleveland, and Los Angeles, where experienced "steel men" will help you select the right tool steel for your needs. At Uddeholm you have an unbeatable combination for quality and delivery.

Write or call on Uddeholm for your tool steel needs.

UHB
TOOL AND DIE STEELS
COLD ROLLED SPRING STEELS

UDDEHOLM COMPANY OF AMERICA, INC.

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Circle 2361 on Page 48-B

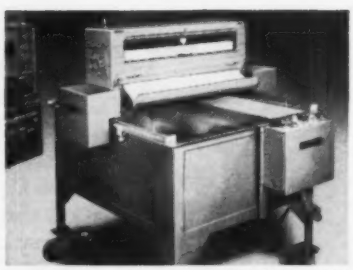
Sonic "eyes" take a piercing look for tiny, hidden flaws in complex steel shapes

Ultrasonic testing for tiny defects in vital parts with a Curtiss-Wright immersed inspection Immerscope is an important phase of the quality program at Standard Steel Works, major supplier of special alloy steel shapes of thin section and intricate forms. Because quality control at Standard is a highly regarded customer service, great emphasis is placed upon securing the most accurate, up-to-date testing equipment available in order to maintain a high level of accuracy.

Immerscope ultrasonic non-destructive testing is extremely versatile and accurate because of its range, rapidity of scanning and its high sensitivity in flaw detection. Variety of shapes and complexity of objects do not restrict complete inspection of the whole unit piece. Depth and relative size of flaws or voids are determined from the spacing and size of the pips on the cathode ray tube screen.

Defects as small as 0.0156" can be detected within the steel part under inspection. The large illustration shows a thin-wall ring, resting on rollers in the tank. The operator is at the controls of Immerscope which provides electronic control and progressive indication of findings as the test is being made.

For additional information phone SWinburne 9-0500 or write:



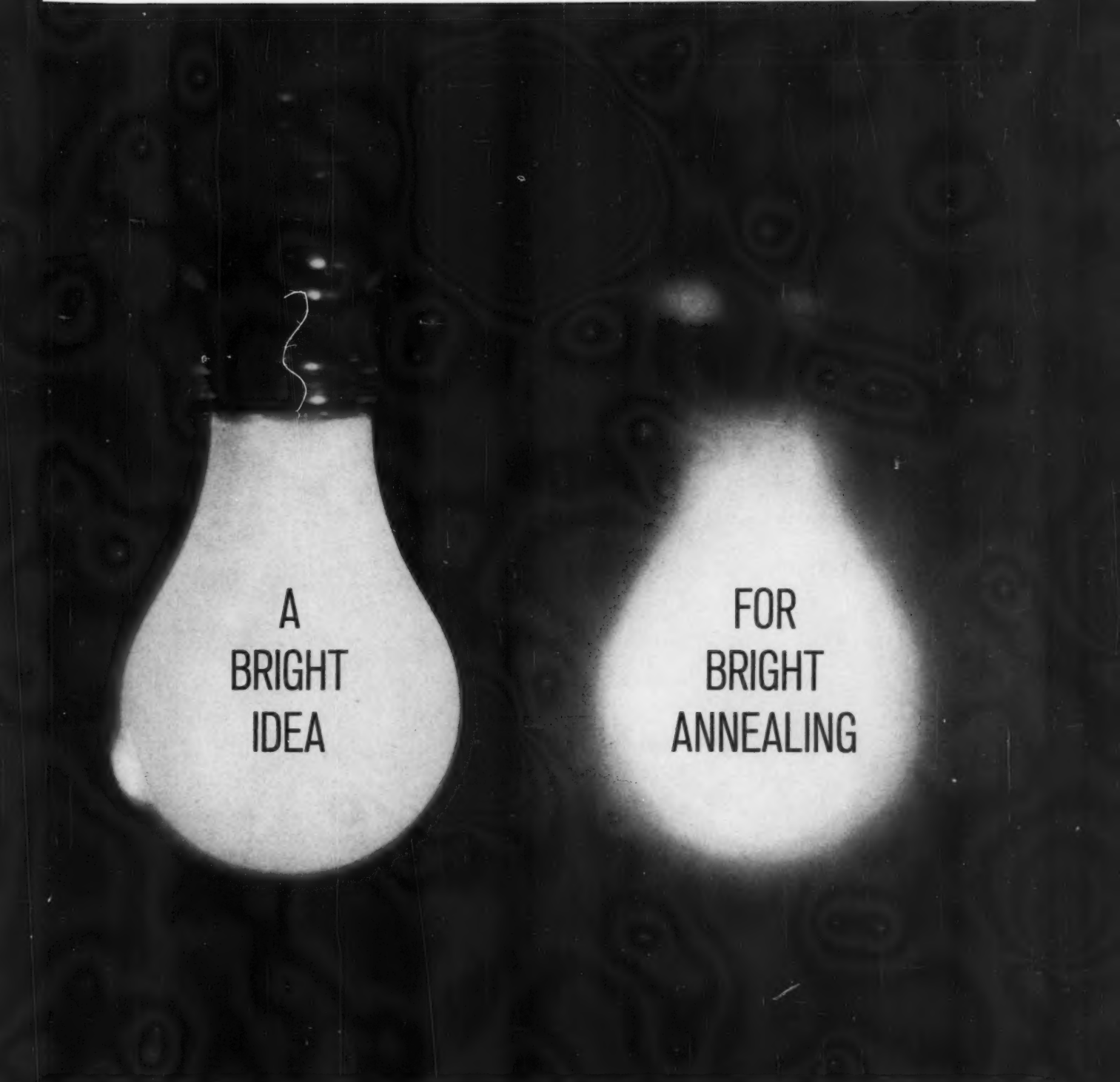
Packaged units are available which range from this small portable unit, having a tank with inside measurements of 4' long x 3' wide x 18" deep, to larger units with maximum dimensions of 54' long x 12' wide.

Princeton Division **CURTISS WRIGHT CORPORATION** Princeton, New Jersey

In CANADA: Canadian Curtiss-Wright Ltd. • 43 Westminster Avenue, North • Montreal 28, P. Q., Canada

Inquiries from qualified Manufacturers Rep. invited.

Circle 2362 on Page 48-B



It takes the right atmosphere to develop brightness in stainless steels during annealing. Dry hydrogen will do it, but a dry N_2-H_2 atmosphere from anhydrous ammonia will do it at less cost. It is the *least* expensive way to supply large volumes of gaseous nitrogen and hydrogen for atmospheres that prevent formation of scale and assure a bright, clean finish.

Allied Chemical Anhydrous Ammonia, dissociated to form a *protective* atmosphere, prevents carburization of metal . . . as a *finish* atmosphere, it prevents discoloration.

It is ideal for: annealing nickel and nickel alloys; electrical steels; beryllium copper; silicon copper; and other copper alloys. Dissociated ammonia is excellent for clean hardening of high carbon and high chrome tool steels . . . for copper brazing of all types of ferrous metals . . . for sintering metal powders.

Our experience with ammonia is unsurpassed by any other producer in this field. Allied Chemical flexibility for shipping ammonia in barge, tankcar, tankwagon, tank truck or cylinders fits every user's needs for saving time and labor.

For specifications and local offices, see our insert in Chemical Materials Catalog, pages 475-482 and in Chemical Week Buyers Guide, pages 37-44.

BASIC TO AMERICA'S PROGRESS

Allied Chemical

NITROGEN DIVISION

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MEMBER METAL POWDER mpi INDUSTRIES FEDERATION

2819

Circle 2363 on Page 48-B

At Kennecott's new refinery... Twin Heroult Electric Furnaces designed

Copper cathodes are charged into the 13,500 KVA Heroult 90-ton electric arc furnace, one of two at Kennecott Refining's new plant south of Baltimore. American Bridge also fabricated and erected the plant's structural framework.

to keep 16,500-ton per month copper melt on schedule

Kennecott Refining Corporation's electrolytic copper refinery near Baltimore is the country's newest—a showplace of efficiency. One reason: a pair of 90-ton Heroult electric arc furnaces, each rated at 40 tons per hour.

Of nose-tilt design to facilitate launder pouring, they discharge a steady stream of molten copper (2150°) which is used in the horizontal casting of wire bars and the continuous casting of billets. One Heroult is on normal capacity operation while the other is a spare for use during relining, when the pre-heat furnace is down, or when additional production is required.

Copper cathodes are preheated to about 1400°F and door charged into the Heroult arc furnace on a peel arm crane. The three-phase power input utilizing ultra-high speed mechanical positioning for three 20" electrodes with high-speed sensitive regulators maintains a constant arc above the copper bath for uniform temperature casting.

The two 90-ton Heroult arc furnaces can be tilted 40° forward and 15° backward. They feature mechanically positioned masts and special water-cooled skew-back roof rings that introduce water flow at the critical roof juncture to prevent warpage and burn out.

Whatever your arc-melt problem there is a Heroult electric arc furnace design for you. We've made them from 3 tons to over 200 tons capacity, for both swing roof top charge or door charge operation. They can accommodate induction stirring equipment, and can be designed for duplexing arrangements. And every Heroult is designed for maintenance by your own crew.

American Bridge has a complete electric furnace service that includes new installation, furnace modernization and part replacement. We'll be happy to quote on your building needs, too. Call our nearest office.

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American Bridge Division of United States Steel

USS

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United States Steel Export Company, New York

This mark tells you a product is made of modern, dependable Steel.

Circle 2364 on Page 48-B

Why is this steel coil half air?

To provide an air-space between each lamination of the coil! This is the key to a revolutionary new method of controlling the composition of steel, known as the Open Coil Process of Gas Alloying. By "opening" the coil and exposing the entire surface to active gases, many exciting things happen to the composition of steel. To name a few: Low grade Bessemer and open hearth steels can be converted to premium products, rimmed steel can be upgraded by decarburization, renitrogenizing and denitrogenizing practices are greatly simplified. The potential is limitless! Mill executives are calling the Open Coil Process "the greatest advance in steel processing in our generation". For complete data call or write . . .

Lee Wilson* **ENGINEERING COMPANY, INC.**

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HIGH PRODUCTION ANNEALING SYSTEMS

MAKE THE BEST METALS BETTER

* ORIGINATORS AND LEADING PRODUCERS OF OPEN COIL AND SINGLE STACK FURNACES

Metal Progress

Vol. 78, No. 6 December 1960

Technical NEWS in Brief

Steel With 9% Nickel Stays Tough at −320° F.

Is it always necessary to stress-relieve welded pressure vessels slated for low-temperature service? This question led to a thorough investigation of the properties of 9% nickel steel, a grade which A.S.T.M. Specification A 300 permits in vessels down to −320° F.

Work carried out by United States Steel Corp., International Nickel Co., Inc., and Chicago Bridge & Iron Co. (a program termed Operation Cryogenics) has revealed that, in addition to vessels fabricated of 9% nickel steel in the double normalized and tempered condition (as recommended by A.S.T.M. A 353-58), those constructed of the same steel in the quenched and tempered condition are satisfactory for service to −320° F. Also, welded vessels fabricated of the 9% nickel grade apparently do not need stress-relief (as is now required by the A.S.M.E. Pressure Vessel Code) to perform safely at −320° F.

These findings have come after considerable laboratory work and low-temperature tests on nine large vessels, two of the tests being made before industry, code-making, government and press representatives at United States Steel's Fairless Works. Vessels tested were either rectangular (8 by 8 by 6½ ft.) or cylindrical (9 ft. long by 4 ft. diam.) and were fabricated of ⅜-in. quenched and tempered or double normalized and tempered plate. Only three were stress-relieved after welding.

Rectangular structures were tested at −320° F. by impact supplied for the most part by a 4350-lb. pendulum capable of providing a blow of up to 82,000 ft-lb.; cylindrical tanks were pressurized with liquid nitrogen until failure by bursting.

Results of the pressure tests point out that as-welded vessels exhibit higher burst stresses than the stress-relieved vessels fabricated from either quenched and tempered or double normalized and tempered 9% nickel steel. Also important is the appearance of the fracture. In the as-welded vessels made from quenched and tempered plate, fail-

Ductile Failure in 9% Nickel Steel Tests at −320° F. Show That Stress-Relief of Welded Vessels Is Not Necessary

ures initiated in a weld seam but occurred in a ductile manner (see photo). Where the tear propagated into the shell, it took the appearance of 100% shear. In comparison, fractures occurring in stress-relieved vessels showed combined shear and cleavage.

As-welded rectangular vessels were tested to demonstrate the ability of 9% nickel steel to absorb shock and exhibit plastic deformation at −320° F. while under internal pressure. Even at −320° F., under repeated blows from the heavy pendulum, failure occurred, not by brittle fracture, but as a result of bending stresses with permanent deformation of the shell plates and internal stiffeners.

Electrolytic Machining Shapes Hard Metals

One of the fundamental problems in metalworking is that the harder the metal, the more difficult it is to machine. The problem is more acute today because of the demands for complex parts made from such materials as the heat resistant superalloys which seem to defy shaping. But this difficulty has not gone unchallenged. Some two and one-half years of work under the direction of C. L. Faust, chief of electrochemical research at Battelle Memorial Institute, has resulted in an electrolytic machining process which can shape parts, sink die cavities, drill holes in tough alloys without concern for their hardness.

Recently demonstrated in Cleveland by Steel Improvement and Forge Co. which sponsored the Battelle research, electrolytic machining has already been used to make over 15,000 turbine blades for jet engines (see photo). To shape a blade, a rough forging which serves as the anode is placed between shaped cathodes. When current is passed between the electrodes, metal is removed from the anode at a rate of 0.05 to 0.1 in. per min. until the anode takes the precise shape of a turbine blade. Because the electrolyte, a weak acid-base solution, is circulated rapidly, it can support a current density of up to 1500 amp. per sq.in. A different electrolyte is required for each alloy.

ELECTROSHAPING TURBINE BLADES
Electrolytic Unit Machines Rough Forgings to ±0.003 In. Tolerance

Besides making it possible to shape difficult materials such as S-816, Waspaloy, Udimet 700, Nimonie' toolsteels and cemented carbides, electroshaping produces no metallurgical changes because stress and heat are eliminated. Sections can be machined down to 0.005 in.

The process can also be adapted to milling operations over long lengths such as machine ways where the absence of tool wear and heat results in good dimensional accuracy. Other applications include drilling of deep and irregular holes in hard alloys and sinking die cavities. The process can also be used as a cutoff tool for slicing bar stock.

Zinc Protects Hot Columbium

There is a well-authenticated story that duralumin (age hardened aluminum) was discovered because a laboratory worker quit at Saturday noon and went fishing instead of testing the sample immediately after heat treatment. Comes now a report that a good coating to prevent the oxidation of columbium was discovered in almost as bizarre a way.

George Sandoz, at Naval Research Laboratory in Washington, was running a long series of tests to determine the oxidation rate of columbium. He used a vacuum furnace containing very small amounts of air. Some slight modifications were made in the furnace, and suddenly the columbium stopped oxidizing. Spectrographic analysis of a film on the test piece and of a cloudy deposit at the cool end of the furnace tube indicated that a little zinc had distilled from two chromium-plated brass screws in a stainless steel fixture!

Intensive study by a team of experts in various branches of science learned that a liquid layer of zinc crawls over the surface of the columbium, even above 2000° F., and is itself prevented from vaporizing by zinc oxide which in turn covers it. (All this at far above the melting point of zinc!) The film doesn't blow away, and it "wets" the columbium so effectively that any scratch or mechanical damage is self-healing.

Auto Industry Looks at Stretch-Forming

A stretch-forming attachment for standard draw presses can save automobile manufacturers 50 to 60 cents per car (or three million dollars based on a six-million-car year). In the process, perfected by the Cyril Bath Co., sheet metal is stretched prior to forming, thus eliminating any tendency of trapped metal to wrinkle Shallow-draw panels, such as roof tops, doors, rear decks, and hoods, can be produced at considerable savings since die costs, maintenance and setup time are reduced. In addition, a 20% saving in material cost is possible because thinner and less costly sheet stock can be used; metal is also saved because a hold-down

ring is not required. A stronger and harder part is produced, and "oil-canning" is eliminated. The process is also applicable to aluminum, titanium, stainless steels and other heat-resistant alloys.

Gas Pressure Compacts Hot Uranium Nitride

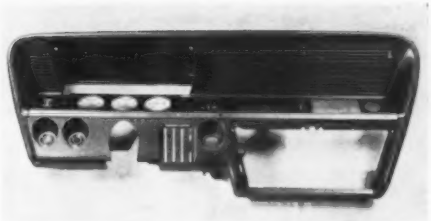
Donald Keller of Battelle Memorial Institute told the audience at the A.E.C.-A.S.M. meeting at the Philadelphia convention some of the schemes devised to make solid compacts of chemically reactive particles which are hard and unyieldng even at high temperature – uranium nitride in particular. A round rod, squeezed together from powder at ordinary temperature and pressure, is slipped into a stainless steel tube, evacuated in a vacuum chamber and sealed tight by electron beam welding. This rod is then connected between electrodes in an autoclave (helium atmosphere) and enough current run through to heat it by resistance to incandescence, meanwhile pumping the helium up to 10,000 psi. The tube collapses uniformly and the uranium nitride compacts to about 80% of theoretical density. Such a rod can be further squeezed to 98% of theoretical density – at least in the surface regions – by wrapping an explosive around it, dropping it into a tank of water, and detonating.

Auto Makers Trim Costs With Magnesium Die Castings

One of the important trends brought out at the recent meeting of the Magnesium Association in Cleveland is that the auto industry is becoming more interested in applications for the light metal. Examples are the dash panels (see photo) on 1961 Chevrolets and Dodge Lancers which for the first time are magnesium die castings. (Other automotive applications for small magnesium die castings are described in A. R. Tinetti's article on p. 82 of this issue.) Magnesium was chosen over zinc on the basis of lower costs made possible because four times as many die castings can be made per pound of metal. In addition, automatic metering on cold chamber die-casting machines and the lower heat content of magnesium allows higher production rates. The Chevrolet dash panel weighs 4½ lb. (trimmed), is about 30 in. wide and 16 in. deep, and has wall thicknesses down to 0.090 in. Finishing of the panels involves a Dow No. 20 treatment, a prime coat and a standard finish coat.

Another paper presented at the meeting described the application of the centrifuge to permanent-mold casting of large, thin-webbed parts (down to 0.080 in.) which are difficult to cast by other methods. Compared to ordinary permanent mold castings, those made by centrifuging have higher mechanical properties and reduced microporosity in critical areas, and the rapid chill produced by centrifuging results in finer grain size and better casting surface.

Other advantages of centrifuging: Closer dimensional tolerances can be applied, more intricate configurations and finer details are possible and faster casting cycles are obtained.



Magnesium Dash Panel
Die Casting for 1961 Chevrolet Results in Low Production Costs

Study Reveals Best Way to Paint Welds

Preliminary studies being carried out by the Steel Structures Painting Council in Pittsburgh have shed some light on corrosion of painted welds and what to do about it. Working with hundreds of welded specimens made from hot rolled steel, investigators have been checking the effect of electrode type, various preweld and postweld chemical treatments, mechanical surface preparations such as wire brushing, sand-blasting and types of primers and finish coats.

The work, reported by J. D. Keane at the recent Fall Meeting of the American Welding Society in Pittsburgh, indicates that spatter is not necessarily the cause of corrosion and paint failure near welds. Spots of rust appear first at sharp points, but most paint failures occur on the smooth face of the plate about ½ in. from the weld. This lends support to the idea that the corrosion is related more to type and amount of alkaline residues, fume deposits, gases, oxides and slag from welding rather than to metallurgical factors such as stress-corrosion or grain size. It is significant that sand-blasting after welding resulted in better performance of paints than either hand or power-driven wire brushing. Chemical treatments, such as dilute chromic and phosphoric acid applied after welding, also improved the performance of paint over welds. In fact, scrubbing the weld with water is almost as effective as the best chemical process. These treatments improve the durability of paint on wire brushed areas and may serve as an alternative to sand-blasting.

Two types of electrodes, E 6010 and E 6024, were used in most of the tests. After three months of exposure, the first 77 painted areas to show deterioration were over welds made with E 6010 electrodes. Paint on E 6024 welds held up just as well as on flat surfaces. Anti-spatter compounds proved rather unpredictable. Some make it easier to remove spatter and benefited paint performance; others were detrimental. Limited tests reveal an advantage to painting with either good vinyl, zinc dust, zinc rich or chlorinated rubber primers.

Got Any Use for Gold?

It is often said that we know the least about the arts mankind has practiced the longest. To a degree that statement applies to gold, one of our most ancient metals. What is it good for, other than a standard of value (money) and in ornamentation (jewelry)? Its corrosion resistance warrants a small use as electroplate, but even in such microscopically thin films its cost is likely to cause a commercial user to hesitate.

N. S. Spence of the Ottawa Chapter ⊜ now tells us that the Canadian Department of Mines and Technical Surveys has been looking into the matter. Canada subsidizes some gold mines, and it seems silly to keep spending more to produce an article than it can be sold for. "Tonnage" use might bring the production cost down, or raise the selling price, or both. Encouragement is also had from the fact that, in this atomic age, many exotic metals costing far more per pound than gold are used in considerable amounts.

There are indications from metallurgical theory that this heavy metal may have pronounced and beneficial effects on the mechanical properties of age hardenable alloys when added in fractional percentages. At any rate, the people in Ottawa are moving in on this extensive area of ignorance about the possible industrial uses of gold in tons rather than in ounces.

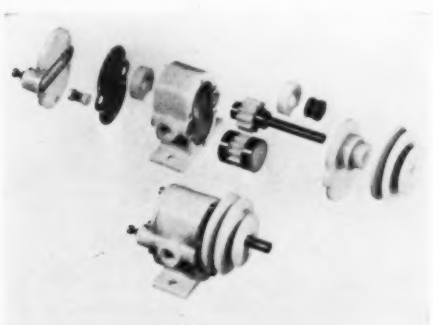
Materials Progress in Nonmetallics

Acetal resin, termed Delrin by E. I. du Pont de Nemours & Co., which introduced it last January, possesses characteristics which have led to its application in a number of important areas (see *Metal Progress,* April 1960, p. 68, and September 1960, p. 68).

Taking advantage of its bearing qualities, engineers at Planet Products, Chicago, have designed pumps which employ Delrin almost entirely. Because the plastic pumps are resistant to chemical attack and water absorption, they are expected to be used in lubricating, cooling and spraying systems, and for general-purpose handling of farm chemicals. They have a capacity of from 2 to 18.5 gal. per min. and can operate at up to 100 psi. with nonlubricating liquids. Additional advantages include noiseless operation, lower power requirements and greater service life than metal pumps.

To use Delrin, Planet engineers designed the pumps so that the operating stresses are distributed over bearing areas which are four times that normally used. The plastic gears have integral hubs over which thin sleeves of brass, bronze or stainless steel are pressed. The hub of the drive gear, also capped with metal, runs in a Delrin bushing, and the idler gear rotates in the internal cavity of the pump thus eliminating the need for a shaft. These metal-to-plastic contacts require no lubrication.

In another application, the acetal resin is being injection molded to make inner door handles for Ford's Econoline trucks. Knobs on the handles are also nonmetallic, a molded nylon which is snapped to the handle.



New Pump Uses Delrin Parts
Plastic Reduces Friction, Doubles Pump Life

From Here and There

Early in July the experts who attended a meeting of the International Federation of Automatic Control spent a week in visiting factories and scientific institutes in Moscow, Leningrad and Kiev. P. K. McPherson, reporting in the British magazine *Nuclear Power* says: "In the factories on view, automation amounted only to transfer machines. The Russians have done important work, however, on control in the steel and power industries, and appear to be applying adaptive control by stages throughout industry."

• • • •

A Japanese auto maker is casting stamping and forming dies which weigh as much as 3½ tons. Produced by the Shaw Process in ceramic molds, these large shapes indicate the potential for making large tools and dies from difficult-to-machine hot work tool steels such as D-5, H-11, H-13 and H-21.

New Carburizing Steels From Germany

Heat treaters, particularly those who are concerned with case hardening processes, will be interested in new carburizing steels developed in Germany and described in the "World Progress and Forecast" issue of *Metal Progress* next month. These steels contain molybdenum as the major alloying element and possess excellent case hardenability.

Other articles in this January issue will point out the advances being made in metallurgy and metalworking in other countries. A special "Technology Forecast" will give technical management a concise report on what to expect in metal technology in the year ahead.

Critical Points

By the EDITORS

Fiber Metallurgy: The Study of Whiskers

THE TOPIC ABOVE IS CONSIDERED sufficiently important in the future of materials to be discussed at some length by the National Aeronautics and Space Administration in its Second Semiannual Report to the President and Congress, printed earlier this year by the Government Printing Office. On p. 118 in this issue of *Metal Progress* you will find an interesting article by Messrs. McDanels, Jech and Weeton on progress being made with metal fiber composites at N.A.S.A.'s Lewis Research Center in Cleveland. Most of what follows here is drawn from N.A.S.A.'s Report. It gives some idea of the new horizons which are opening up for "whisker metallurgists".

We have known for a long time that metals are far weaker than they should be according to physical theory. The reasons are many, principally imperfections in the crystal architecture. When crystals are grown with little or no imperfection, they show almost incredible strength.

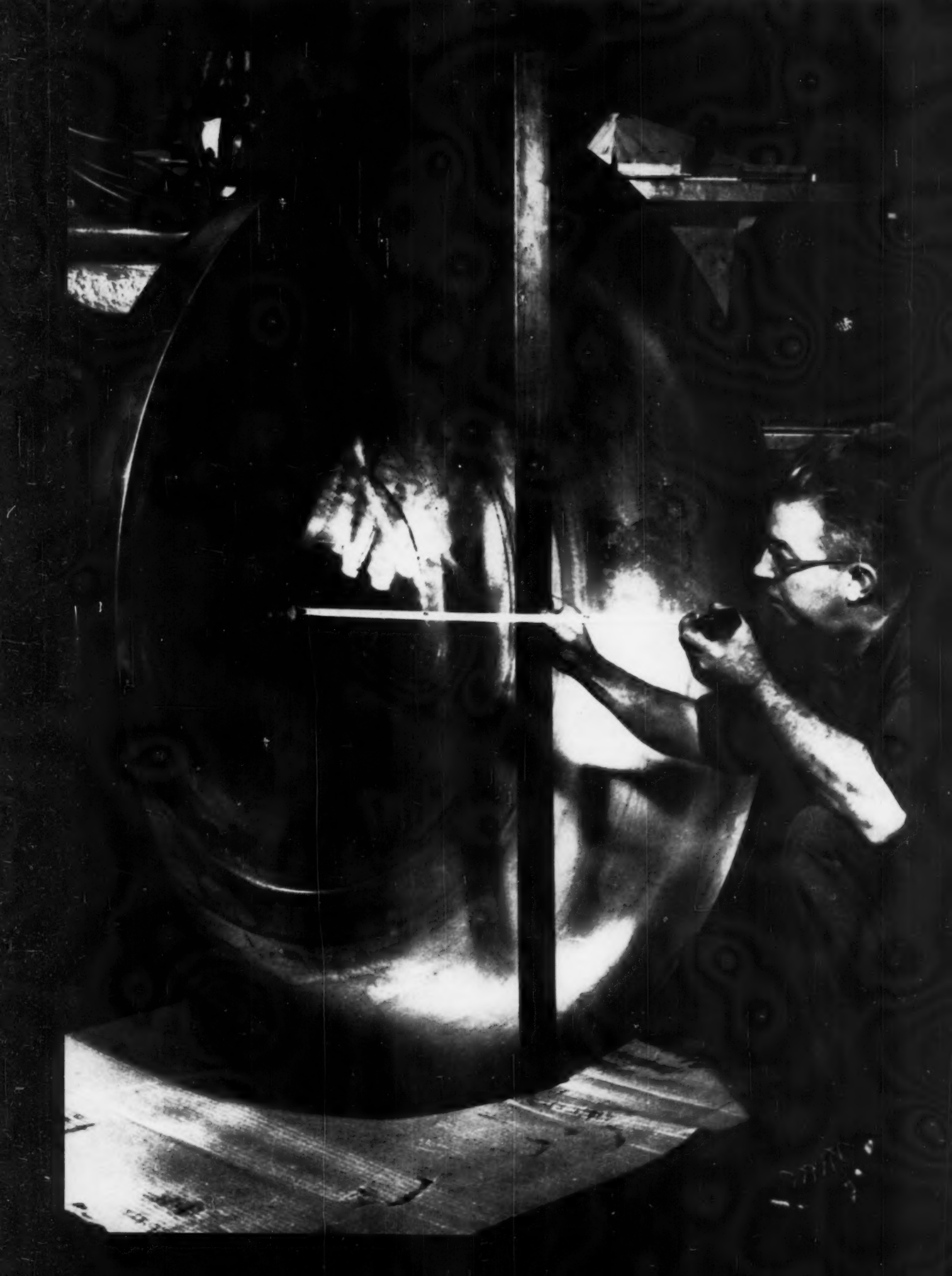
A study of metallic "whiskers", so called because of their appearance, cast light on this problem. Microscopic metal fibers (diameter less than one ten-thousandth in.), which can be grown from the vapor phase or by electrolysis of a molten salt, have a tensile strength almost as high as 2,000,000 psi. compared with 350,000 psi. for some of the best modern steels when tested in macroscopic size – say 0.505 in. diameter. Thus, if the full strength of whiskers could be utilized in a practical engineering material, it would be so strong that useful components made of it could be greatly reduced in size and weight. Of national significance is the fact that rockets and missiles could be lightened and payloads increased significantly.

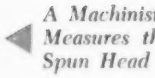
It is difficult to experiment with fibers as short or as fine as actual metallic whiskers. True "whiskers", as defined above, are not made commercially but it is recognized that some of their great strength is derived from their fine diameter. For example, the finer a wire is drawn, the greater its strength per unit area. While it is obvious that much of the strength of wire is due to the cold work necessary for producing it, research on utilization of fine wires may help us until true whiskers become available.

The first experiments of this nature have utilized fine, strong wires. Other studies using tungsten wires in a copper matrix have shown that, when the fibers run continuously from one end of a specimen to another, the composites have a strength proportional to the number of fibers in the specimen and also to the strength of these fibers. Thus, as reported on p. 118, copper, having a strength of 30,000 psi. is strengthened to more than 120,000 psi. by adding 35% of tungsten fibers (having a strength of 300,000 psi.).

Another important finding is that the same strengths can be had in tungsten-copper composites reinforced with very short lengths of fibers that do not extend from one end of the specimen to the other. This reminds us of concrete, reinforced by short lengths of overlapping rods. It follows, then, that if very short, but very strong, whiskers could replace the long wire filaments without lowering the whisker strength, the product would be unusually strong. In addition, there are many possibilities for combinations of metals with ceramics in composites of this type.

Thus, it is evident that to solve many of our future problems in structural materials the metallurgist will find that more and more he must be part scientist and part engineer. This is good – a dynamic technology must expand, or it will stagnate.





A Machinist at Aerojet-General Measures the Dimensions of a Spun Head for a Rocket Motor

Spinning Makes Stronger Rocket Cases

*By LEWIS E. ZWISSLER**

When many early rocket cases failed in weld zones, designers attempted to minimize the number of welds. Shear spinning appears to be a good method for fabricating surfaces of revolution which would require a minimum of welding for rocket cases. (G13, T2p; AY)

THE EARLY HISTORY of rocket motor cases has been troubled by a number of failures. Since many of these failures were found to start with defects associated with welded joints, it seemed that the obvious answer was to reduce the number of welds in the case. While there are several ways to do this, it was felt that the shear spinning process – a method by which curved parts can be made in one piece from high-strength alloys – was the best.

The Shear Spinning Process

Described briefly, in the shear spinning process a blank, which may be either flat or preformed to some shape, is clamped between the tailstock of the shear spinning machine and a power driven spinning mandrel. The contour of the mandrel, as Fig. 1 shows, is the same as the inside surface of the finished part, and the material is forced to flow onto the mandrel by the forming rollers' action.

Figure 2 illustrates a modern shear spinning machine; it can form parts up to 66 in. in diameter and 62 in. long. This machine is made with two opposing rolls to lessen mandrel deflections. (In some instances, three rolls at 120° are used.) To maintain a constant wall thickness, rolls are mounted on slides with hydraulic load cylinders which can withstand the forming loads. Clearance between rolls and mandrel is maintained by contour templets that control the roller position.

Though this process appears to be similar to conventional spinning, there is a fundamental difference. The material is deformed in *pure* shear, as is illustrated in Fig. 3. To explain further, when an annular element (which shows

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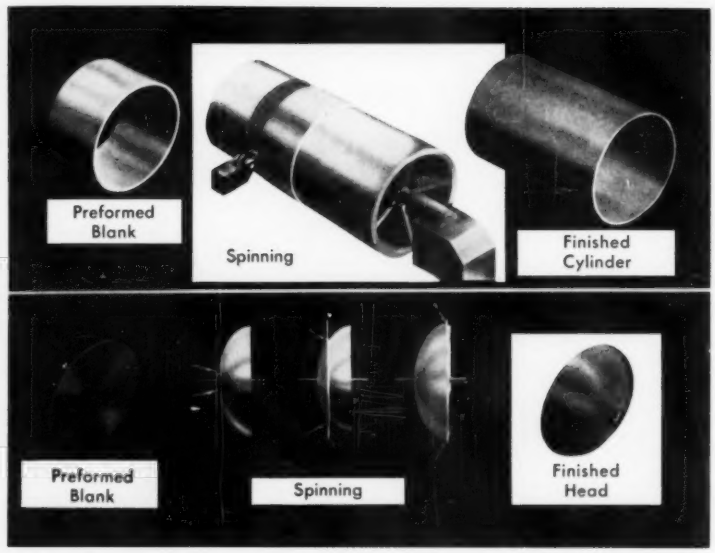


Fig. 1 – How Shear Spinning Works. The preform is positioned on a mandrel which conforms to the inside dimensions of the part. Then, the small rolls force the preform into the required shape as the mandrel spins

as a rectangle in cross section) is moved parallel to the axis of rotation, it is deformed – but the original thickness, t, has remained unchanged. Now, however, the thickness perpendicular to the finished surface has become t_1; this deformation can be expressed mathematically as "t sine θ".

If a tapered wall thickness is desired, the blank is preshaped with the thickness varying so that the final taper is obtained. In fact, this was the first problem encountered in spinning the elliptical heads for the case.

The final shape of this head blank (illustrated in Fig. 4) includes provision for a

Fig. 2 – Modern Shear Spinning Machine. This model can form parts which are up to 66 in. in diameter and 62 in. long. Forming rolls are set 180° apart to minimize deflections in the mandrel

thickened area which is needed for a mechanical joint. This area moves axially as spinning proceeds, and is finally located in the head at the same radial distance as in the starting blank. The blank is designed so that thickness increases gradually, starting at the center.

In actual practice, it was found that the internal diameter of the preform did not lay down tight on the preform mandrel. However, if the diametrical clearance was maintained below 0.180 in., the final head could be spun tight to the mandrel on the final forming shape.

Our Program for Case Manufacture

The manufacturing program was begun by selecting a modified A.M.S. 6434, an alloy containing 0.33 to 0.38% C, 0.60 to 0.85% Mn, 0.40 to 0.60% Si, 0.65 to 0.90% Cr, 1.65 to 2.00% Ni, 0.30 to 0.40% Mo, and 0.17 to 0.23% V. As for the other requirements, when the alloy was oil quenched from 1625 ±25° F. and tempered for 2 hr. (min.) at 400 to 500° F., it had to have a yield strength of 210,000 psi. (0.2% offset) and an elongation (in 2 in.) of 6%.

During the course of the program, shear spinning techniques were devised for subscale cylindrical shells and cones, and investigations of metallurgical aspects were conducted (preparation of the material for shear spinning, in-process annealing, and final heat treatment). Spinning of cylindrical sections was perfected, and preform and shear spinning methods for elliptical heads were developed. Assembly, heat treating, final machining, and hydrostatic testing completed the work.

As the first step in the program, the formability of the alloy had to be determined. Two shapes were chosen which would represent the extremes of the problem which would be encountered in shear spinning the elliptical head shape and the cylindrical section. In forming these shapes, investigations were made of the metal's resistance to deformation by shear spinning, the number of passes needed to obtain the desired reduction in metal thickness, the

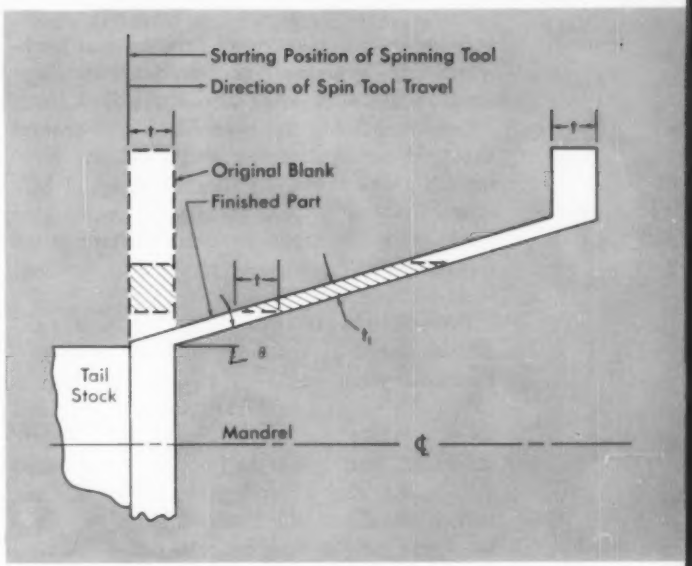


Fig. 3 – Theory of Shear Spinning. Deflection is in pure shear in that the deformed metal moves laterally only. As can be seen, the shaded area is positioned at the same distance from the center line both before and after spinning. This phenomenon aids design in that the thickness of the deformed zone conforms to the sine law. In other words, $t_1 = t \sin \theta$

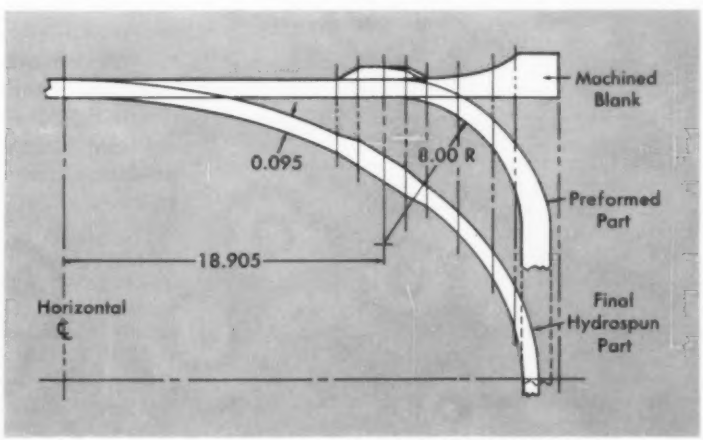


Fig. 4 – How the Elliptical Head Was Formed in Two Shear Spinning Operations. The preform was spun from the machined blank, annealed, and respun to final dimensions. Note that axial dimensions (wall dimensions parallel to center line) remain the same throughout the two spinning operations

optimum percent reduction on each pass, feeds, and speeds. Evaluation of forward and backward tube spinning*, and methods for heat treating the alloy were also studied.

Before spinning the cone blank from round sheet, 16 in. in diameter and 0.200 in. thick, the alloy was annealed† to a minimum of 85% spheroidization with a maximum hardness of Rockwell B-92. Since the deformation obeyed the sine law, the parts were spun to the final form without any difficulty.

Investigation of tube spinning was conducted on 14 in. diameter subscale cylinders. Preforms were made in two ways, from a rolled ring forging, and from rolled and welded sheet. While the rolled ring forgings were machined, both inside and out, to the finished dimensions, the welded preforms were used with a standard mill finish (though the weld bead was ground flush on both sides). A total of 25 cylinders were spun, six of them being made with welded preforms.

Annealing Methods Studied

Since it was impossible to get the desired reduction in one pass, investigation of the need for interpass annealing was necessary. To do this, steel was obtained from the mill in the spheroidized condition, machined to the proper blank size, and spun. Samples of the spun material were annealed by two methods: isothermal annealing and subcritical stress-relief annealing‡. Next, metallurgical samples were examined, photomicrographs were made, and hardness readings obtained from the material as-received, after spinning, and after each of the three anneals. See Table I for the results.

Though shear spinning caused considerable plastic deformation in the spun alloy, a spheroidizing anneal removed this deformation, producing completely spheroidized carbides in equiaxed grains of ferrite.

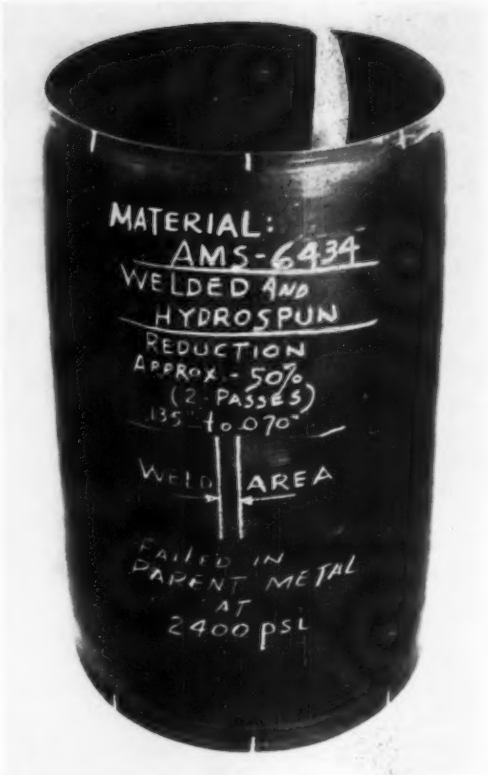


Fig. 5 — Hydrostatic Pressure Test of Shear Spun Cylinder. After withstanding a hoop stress of 229,000 psi., it failed in the parent metal 180° from the weld zone

*The term "forward tube spinning" is used when the preform is clamped to the head stock and the forming rolls move in a direction from the head stock toward the tail stock. The material to be deformed is pushed ahead of the forming rolls while the material of finished stock thickness is placed in tension between the head stock and the forming roll.

The term "backward tube spinning" is used to describe the operation where the preform is placed on the mandrel and shouldered against the head stock face plate, and the forming rolls move in a direction from the tail stock toward the head stock. The material which is being deformed is forced to flow underneath the forming rolls away from the head stock. The portion of the preform which has not been acted upon by the rollers is placed in compression. In effect, the deformed material, is extruded underneath the forming rolls in a direction opposite from the way the rolls are moving. In some instances the term "forward extrusion" and "backward extrusion" are used interchangeably with "forward tube spinning" and "backward tube spinning", respectively.

†The preformed blank was packed in steel chips and heated in a retort to 1450° F. in 36 hr. After holding at temperature for 15 hr., the load was furnace cooled at 20° F. per hr. to below 800° F. and removed from the furnace. Since the cooling took 33 hr., total time in the furnace was 84 hr.

‡Isothermal Anneal: The specimen was sandwiched between two ½-in. steel plates and austenitized in an argon atmosphere. After holding at temperature (1600° F.) for 20 min., it was rapidly transferred to another furnace operating at 1220° F., held for 7 hr., and air cooled.

Subcritical Stress-Relief Anneal: The sample was placed in the furnace at 1250° F., held for 45 min., and air cooled.

As for the other treatments, isothermal annealing produced a lamellar structure, and the subcritical stress-relief resulted in a spheroidized condition. However, the latter treatment did not lower the hardness level enough to permit subsequent spinning without rupture.

Table I – Results of Annealing

Condition	Structure	Rockwell Hardness
As received, mill spheroidized	Spheroidized	B-91
As spun	Cold worked	C-27
Spun and re-spheroidized	Spheroidized	B-90
Spun and subcritical stress-relieved	Lamellar	B-94
Spun and isothermally annealed	Spheroidized	B-95.5

The results of the subscale program are summarized as follows:

- Better dimensional accuracy was obtained when using diametrically opposed rollers and making the reduction in two passes (rather than attempting to offset the rollers to achieve the same amount of reduction in one pass).
- The accuracy obtained in tube spinning was greater when the backward extrusion process was used, the cylinder remaining tight on the mandrel to give better dimensional control.
- The maximum hardness which could be successfully spun was Rockwell B-92 with the material annealed to a minimum of 85% spheroidization. Pure shear spinning was performed with ease on 67° cones.

The success of the subscale program is demonstrated by Fig. 5. It illustrates a welded preform hydrospun to a reduction of about 50% in two passes to give a final wall thickness of 0.070 in. After being heat treated to a uniaxial yield strength of 210,000 psi., the vessel failed under hydrostatic internal pressure at a calculated hoop stress of 229,000 psi. The parent metal ruptured 180° from the weld seam.

Spinning Cylindrical Sections

Because of this prior experience, there was no difficulty in forming full-sized cylindrical shells. Wall thickness was reduced 65% in two passes, though it was necessary to re-spheroidize anneal after the first pass to obtain optimum properties for the final reduction. Rolled and welded shells were used in manufacturing five cylindrical preforms. Though one of these was not spun (because of bad geometry) the remaining four were spun successfully.

Of the seven cylinders spun from preforms which were machined from forged blanks, only two were unsatisfactory – and this was due to a variation of 0.045 in. in the wall thickness of the preform. These two pieces were used for tool tryout. After one piece was spun (using the rear extrusion technique), the part was loose on the mandrel, badly buckled and contained numerous fractures. The second bad blank was spun by the forward extrusion technique in hopes that the tendency to buckle would be minimized, but results were the same as before.

During the first attempt to spin the large shells, feeds and speeds which had been most successful during the subscale program were used. However, the finished cylinders were not tight on the mandrel, and it was necessary to increase the centrifugal speed to 1050 ft. per min. with a longitudinal feed of 0.040 in. per revolution. This made the part tighter on

Fig. 6 – After Spinning Is Completed, the Cylinder Is Inspected for Dimensional Accuracy. In this case, diameter varied 0.011 in. and thickness varied less than 0.004 in.

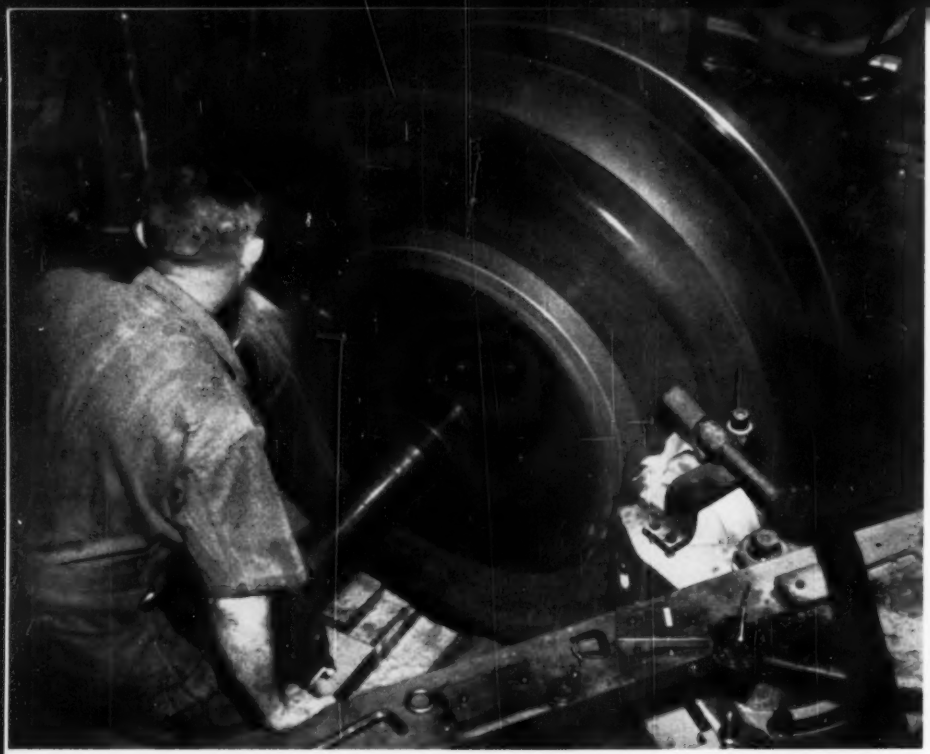


Fig. 7 – Hydrospinning the Forward Elliptical Head. Large diameter tailstock pad is being positioned

the mandrel, and gave it a better surface finish. In spinning the large shells, compensating for the machine deflections was the biggest problem. These deflections caused the part to taper in wall thickness from end to end since the deformation was a function of the position of the load imposed on the mandrel and the frame. In addition, the absolute value of the final thickness was affected.

When the tracing templet was shimmed to compensate for these deflections, it was possible to spin a 54-in. diameter shell approximately 45 in. long with a nominal wall thickness of 0.100 in. and a variation in thickness of less than 0.004 in. Outside diameters were held as close as 0.010 in.; however, in some shells the variation was as high as 0.075 in.

A picture of a completed cylinder is shown in Fig. 6 in which it can be stated that the operator is making a thickness survey and recording the thicknesses on the shell. In this particular case, a variation in diameter of 0.011 in. was obtained with a total thickness variation of less than 0.004 in.

Spinning the Elliptical Heads

The first problem encountered in spinning the elliptical heads for the case was in determining dimensions of the preform blank. Starting with a flat circular blank, the varying thicknesses for the contour of this preform were calculated. For these calculations, the sine law was used for the material which fell outside an inclined cone angle of 67°. That portion of the blank which formed the cylindrical section of the head was calculated on a straight volumetric reduction as in tube spinning, and for the intermediate area, estimation was made of the needed blank thickness relying on experience gained in designing other parts of similar geometry.

However, when attempts were made to spin the preform blanks machined according to these assumptions, severe back extrusion occurred in the intermediate area in the final preform spinning pass. On investigating this, it was decided that too much material was present in the blank at these areas. Consequently, a revised blank illustrated in Fig. 4 was developed, and it proved successful.

Several other difficulties became evident when spinning the head sections – difficulties that served to emphasize again the importance of many factors which influence the shear spinning process. For example, imperfections in the sheet stock caused one failure during the preliminary work. When a surface rupture occurred near the outside edge of the part, the failure area was examined, and it was found that the rupture occurred where some inclusions had been torn out to a depth of about one-third the metal thickness. From then on, all blanks were inspected (by magnetic particle techniques) between each spinning operation

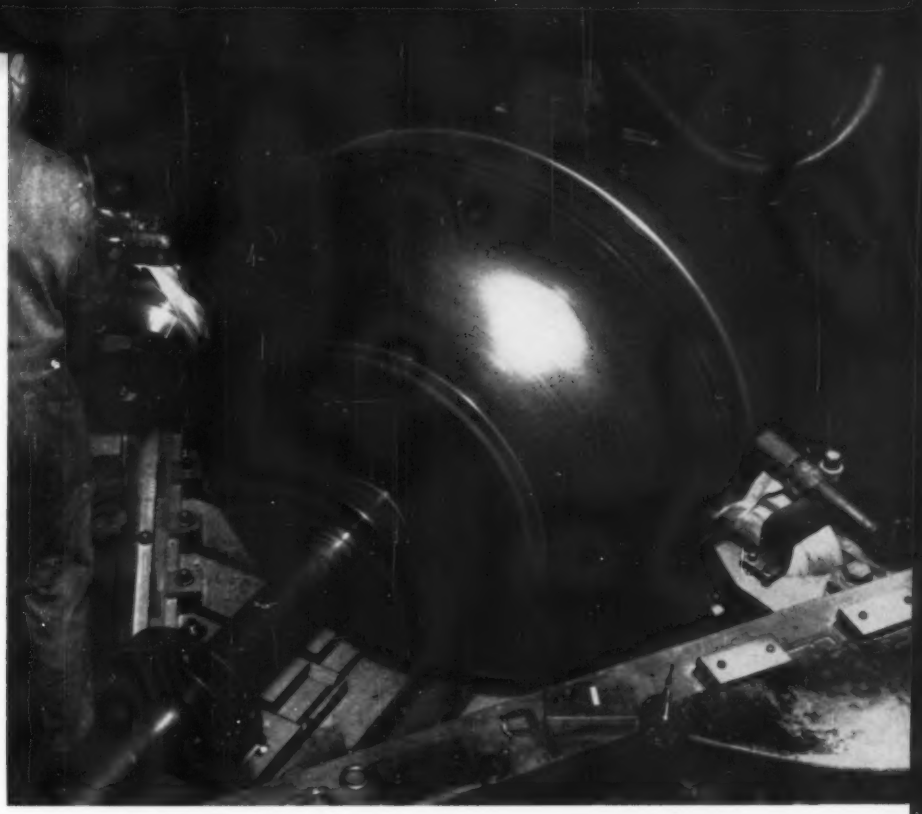


Fig. 8 – Forward Elliptical Head After Spinning Is Finished

and in the final form. Any surface defect or material fracture was either removed or, if severe enough, was cause for rejection.

Another problem occurred because of the processing used in preparing the flat blanks. One of the preforms fractured with a radial crack; the cause was traced back to sharp marks produced by the Blanchard grinder. Tool marks which were excessively deep caused other fractures, and some cracks occurred at these points during subsequent heat treatment. A No. 80 grit grinding wheel was needed to obtain the required surface finish.

Since it was impossible to form the preform tight to the mandrel, it was necessary to reduce the diameter of the preform mandrel so that the resultant spring back gave the preform a finished internal diameter with a maximum diametrical clearance of 0.180 in. over the finished form mandrel. In some instances a total of four preform passes with two in-process short-cycle annealing treatments was made. After the preform was spun, it was placed on the final form mandrel, and the area at the center of the head was spun without using a tailstock. When spinning had gone far enough, a large-diameter tailstock pad was pushed into place as Fig. 7 shows. This pad helped reduce the back extrusion toward the center of the head.

The use of a preformed A.I.S.I. 1020 steel overlay which was spun over the finished heads was tried as a method of correcting areas which were slightly back extruded or too large in diameter. This method improved the contour of the parts, and did not affect the wall thickness appreciably. The finished head is shown in Fig. 8.

As a result of the spinning of the elliptical heads, it was concluded that the steel must be free of inclusions, the surface of the machine blank must be free of sharp tool marks, a tolerance of ± 0.002 in. might be beneficial in obtaining reproducible accuracy, and a tool ring with a radius of $\frac{1}{8}$ in. should be used in the final spinning pass. The preform shape with the 8-in. radius was not satisfactory, and a sharper radius is probably more desirable.

Summary – Using shear spinning to form the major components of a rocket motor offers many possibilities. In addition to the shear spinning investigations, problems such as welding, assembly, final machining, and heat treating of a thin wall were solved. As proof of this, the final chamber was hydrotested to a pressure equivalent to a calculated hoop stress in excess of 200,000 psi.

In those shapes which include curvilinear elements such as the elliptical head, it is difficult to develop blanks and preform shapes which will provide the contour and thickness accuracy needed. Further work is being done to devise techniques for producing large elliptical heads in quantities.

Does Silicon Accelerate Decarburization?

*By PETER PAYSON**

Not in medium-carbon alloy steels, according to the author. In offering data to show that silicon actually promotes separation of ferrite from austenite on cooling, he concludes that the excess ferrite at the surface of steels high in silicon has been attributed erroneously to decarburization. Elements added for more hardenability (chromium and molybdenum, for example) will negate this effect. (J4a, J5, 2-60: AY, *Si*)

THE EFFECT OF SILICON on hardenability — it causes ferrite to be rejected from austenite in cooling — has, we feel, been misinterpreted by researchers for many years. As a consequence, most of today's metals engineers are under the mistaken impression that silicon promotes decarburization in medium-carbon steels. While we concede that the subject is somewhat controversial, we think the time has come for a careful reappraisal of the facts.

How We Began Our Work

Some years ago, during the course of a program for alloy steel development, it became desirable to establish how the various alloying elements affected the separation of ferrite from low-carbon austenite as it cooled from a high temperature. (Although many investigators have worked a great deal to determine the effects of alloying elements on the hardenability of low-alloy steels, nothing seemed to have been published on the specific correlation of alloy content and ferrite separation.) To fill this gap in our information, a series of low-carbon (about 0.20%) steels was made up in small induction heats. After forging them to 1¼ in. square bars, small pieces (1/16 by ½ by ½ in.) were sectioned and heated at 2100° F. (in a

*Assistant Director of Research, Crucible Steel Co. of America, Pittsburgh.

Table I – Ferrite Separation at High Transformation Temperatures

Bar	C	Alloy	Ferrite in Structure, %								
			Seconds at 1400° F.			1300° F.			1200° F.		
			5	15	60	5	15	60	5	15	60
1	0.19	1.7 Mn	0	0	0	0	1	2	1	5	25
2	0.20	3.5 Mn	0	0	0	0	0	0	0	0	0
3	0.21	1.1 Mo	1	5	25	0	1	10	1	2	10
4	0.20	2.2 Mo	1	5	25	0	1	5	0	0	0
5	0.22	1.9 Cr	1	2	20	5	10	30	2	5	20
6	0.22	3.9 Cr	0	0	0	0	0	2	0	0	0
7	0.20	2.2 Ni	0	0	0	2	15	25	20	40	60
8	0.21	4.2 Ni	0	0	0	0	0	0	1	2	5
9	0.19	1.4 W	1	10	50	2	10	40	20	40	50
10*	0.21	0.8 V	2	25	80	20	50	95 (5)†	5	30	90
11	0.18	1.1 Cu	10	30	40	25	30	60	50	60 (2)†	70 (15)†
12‡	0.19	1.2 Si	20	40	50	25	50	70 (2)†	50 (10)†	50 (25)†	50 (40)†
13‡	0.19	1.9 Si	25	40	60	50	70 (5)†	70 (20)†	60 (10)†	60 (25)†	60 (35)†
14	0.19	0.8 Al	30	40	60	40	50	70	30	40 (10)†	70 (15)†
15‡	0.21	2.5 Co	25	40	50	60 (1)†	70 (20)†	70 (25)†	40 (20)†	50 (30)†	60 (30)†

*Slight amount of residual carbide at 2100° F.
†Transformation product other than ferrite.
‡About 1% ferrite formed during water quench from 2100° F.

nondecarburizing atmosphere) for about 5 min. Then they were quenched in salt baths to 1400, 1300, or 1200° F., held for 5, 15, or 60 sec., quenched into water, and finally were examined for microstructure.

The compositions tested and the results obtained are given in Table I. From these data it seems clear that manganese, nickel, chromium and molybdenum retard the separation of ferrite; silicon, aluminum and cobalt accelerate it; and vanadium, tungsten and copper have relatively little effect on ferrite separation.

These results agree reasonably well with the multiplying factors for manganese, nickel, chromium and molybdenum used in calculating the hardenability of low-alloy steels. However, the negative effects on hardenability of silicon, aluminum and cobalt are somewhat surprising. Since both silicon and aluminum are known to raise the A_3 temperature of steel, it might be argued that the tendency for ferrite to separate from austenite is related to the spread between

Table II – Composition of Experimental Steels

	LaBelle Si No. 2	LaBelle HT	AthaPneu	Halvan
	S5*		S1*	L2*
Carbon	0.56	0.44	0.52	0.53
Manganese	0.7	1.3	0.3	0.7
Silicon	2.0	2.2	0.2	0.3
Chromium	0.2	1.3	1.3	1.1
Vanadium	—	0.3	0.2	0.2
Tungsten	—	—	2.6	—
Molybdenum	0.3	0.4	—	—

*A.I.S.I. designation.

the A_1 and A_3 temperatures of the steels.

This is refuted, however, by the behavior not only of the chromium and molybdenum steels (which have high hardenability in spite of raised A_3 temperatures), but also of the cobalt steel (which has low hardenability, yet does not have an A_3 temperature above that of unalloyed iron). For the moment there appears to be no simple explanation for the effects of silicon, aluminum and cobalt on ferrite separation during the high-temperature transformation of austenite.

Now, however, the question is "Does this effect of silicon – it apparently accelerates the high-temperature transformation of low-carbon austenite – account for the long-existing opinion that high-silicon steels are more susceptible to decarburization than low-silicon steels?" To explain further, let us examine the data of Bars 1 and 12 of Table I. If bars of the same size – representing each heat, of course – are quenched in the same quenching medium (agitated oil, for example), Bar 12 would show free ferrite at the surface after the quench, but Bar 1 would not. Let us assume that each steel was made with 0.50% carbon, and that, in the course of processing to a given diameter, each steel was decarburized to the same extent so that the surface carbon in each steel was 0.19%, the same as that of Bars 1 and 12. Now, when the decarburized bars are quenched into agitated oil, there will be free ferrite at the surface of the 1.2% Si steel (Bar 12) but not in the 1.7% Mn steel (Bar 1). Obviously, the latter would have a higher surface hardness.

It would appear, therefore, that the silicon steel had been decarburized to a greater extent than the manganese steel. Actually, however, the free ferrite structure and lower hardness at the surface of the silicon steel are attributable not to greater amount of decarburization (since both steels were decarburized the same amount) but to the lower hardenability at the surface of the low-carbon silicon steel (in comparison with that for the surface of the low-carbon manganese steel).

Further Work Needed

To check this reasoning, steels with the compositions listed in Table II were tested. Small pieces of each steel with freshly cut surfaces were exposed in the same type of furnaces – electric muffle furnaces without atmosphere control – to the conventional austenitizing temperatures for hardening each grade. Periods of ½, 1, and 2 hr. were employed. After each heating period, the pieces were quenched to the M_s temperature of the steel and tempered immediately. By this technique*, which is completely independent of hardenability, depth of decarburization could be determined conveniently and with precision.

Other sets of pieces representing each grade were heated at 1900° F. for periods of 30 min.

Table III – Depth of Decarburization After Several High-Temperature Exposures

Treatment	LaBelle Si No. 2	LaBelle HT	AthaPneu	Halvan
½ hr. at AH* temperature	0.001 in.	0.005 in.	0.004 in.	0.003 in.
1 hr. at AH temperature	0.006	0.006	0.011	0.006
2 hr. at AH temperature	0.007	0.011	0.013	0.011
1900° F. ½ hr., air cool, reheated ½ hr. at AH	0.015	0.013	0.015	0.012
1900° F. 2 hr., air cool, reheated ½ hr. at AH	0.025	0.026	0.033	0.025
M_s temperature	490° F.	510° F.	630° F.	600° F.

*AH = austenitizing temperature for hardening: 1650° F. for LaBelle Si No. 2 and Halvan; 1700° F. for LaBelle HT; 1750° F. for AthaPneu.

*"Martensite Reactions in Alloy Steels", by P. Payson and C. H. Savage, *Transactions* A.S.M., Vol. 33, 1944, p. 261. To describe this technique simply, in a given steel the M_s rises as the carbon drops. Thus, when the steel is quenched to the "core" M_s temperature, partial transformation to martensite occurs in the decarburized "case". Immediate tempering darkens this martensite. When the sample is quenched to room temperature and processed to reveal the structure, the decarburized zone is marked by the presence of dark patches of tempered martensite in a matrix of untempered martensite. The limit of decarburization is marked by the disappearance of tempered martensite.

and 2 hr. (in electric muffle furnaces without atmosphere control) and air cooled to simulate billet heating for bar rolling. Without further preparation these pieces were processed, as described in the footnote, to determine the depth of decarburization which had occurred at 1900° F. They were reheated in salt baths to prevent further decarburization. The results shown in Table III proved conclusively that the two silicon steels (the "LaBelles") are not more susceptible to decarburization than are the other two steels.

Samples of each steel were austenitized in an electric muffle furnace for 1 hr., quenched in salt baths to 1300° F. (the two LaBelles and Halvan) or 1400° F. (AthaPneu). These were the optimum temperatures for separation of ferrite in each steel.

Finally, they were held for 15 to 60 sec. at each temperature to permit ferrite to form in the decarburized portions. The resulting data, presented in Table IV, show that the percentage of the total depth of decarburization occupied by ferrite is much greater for a given holding time in the LaBelle Si No. 2 (S5) steel than in the others. At the same time, the other high-silicon steel, LaBelle HT, does not show much apparent decarburization. The reason for this should now be clear. The second steel, in spite of its high silicon, has high hardenability because of its high manganese and chromium contents. It is for this reason that the high-silicon steel, "Hy-Tuf" (A.M.S. 6418), has never been known to be subject to excessive decarburization during fabrication and heat treatment.

Table IV – Depth of Ferrite in Decarburized Portion

Holding Time	LaBelle Si No. 2		LaBelle HT		AthaPneu		Halvan	
	F*	F/T	F	F/T	F	F/T	F	F/T
15 sec.	0.004 in.	67%	0.0004 in.	7%	0.004 in.	36%	0.001 in.	17%
30	0.006	100	0.002	33	0.005	45	0.004	67
60	0.009†	—	0.003	50	0.008	73	0.006	100

*F = depth of ferrite; F/T = percentage of total depth of decarburization (shown in Table III for 1 hr. at AH temperature) occupied by free ferrite.

†Ferrite was also observed in matrix.

An Explanation

Undoubtedly, silicon is believed to increase the susceptibility of medium-carbon alloy steels to decarburization because the test for decarburization involves not only the loss of carbon at the surface of the steel, but also the hardenability of the steel at the surface. Actually, the test generally used, instead of measuring carbon content at the surface of the steel, reflects the transformation characteristics of the austenite in the steel at the surface. This is true whether the method depends on the appearance of the subsurface microstructure after a specified heat treatment, or whether it depends on a hardness test after a quench. The data of Table I show clearly that 0.20% carbon steels have considerable differences in hardenability depending on the alloy content of the steel, and that silicon effectively lowers the hardenability of steel with this carbon content.

But this effect of high silicon can be compensated for by adding to the steel enough alloying elements – manganese, nickel, chromium and molybdenum, for example – to raise the hardenability. In the relatively low-hardenability toolsteel, LaBelle Si No. 2 (S5), high silicon appears to increase the susceptibility to decarburization. In Hy-Tuf and LaBelle HT high silicon does not show the "apparent" increase in susceptibility to decarburization because these steels have high hardenability.

The user of the steel is interested primarily in whether or not he can attain a minimum surface hardness in a part after heat treatment. If he gets a low hardness and he believes that decarburization is the cause, he will be able to do little, if anything, about it. But if he knows that hardenability factors are involved, he may be able to compensate for low hardenability by changing either the composition of the steel, the type of quenchant, or the size of the part. The data presented here show that in steels containing high silicon, consideration should be given to the hardenability factors.

These Auto Parts Are Die Cast of a Magnesium Alloy, AZ 91 B. Included are oil filter and fuel pump components

Magnesium Die Castings for Automobiles

*By A. R. TINETTI**

When it appeared that magnesium would have certain economic and production advantages for die castings, engineers at General Motors began an intensive development program. It was successful, and, today, seven types of parts weighing up to ½ lb. are being cast of AZ 91 B magnesium alloy in cold chamber die-casting machines. Larger parts are being considered for the future. (E13, T21; Mg)

EARLY IN THE '50s, we at AC Spark Plug realized that magnesium die castings have economic and physical advantages for certain products and we began an extensive development program. Starting with the purchase of a 400-ton cold chamber die-casting machine (along with a gas-fired melting pot furnace), we made and tested many castings of varied types. Also evaluated were several metal feed systems as well as a large number of tooling designs.

This program was so successful that today, ten years after it was started, we have six die-casting machines which are producing seven different castings from magnesium alloys. Included among them are oil filter and fuel pump parts weighing up to ½ lb. per casting. Furthermore, facilities are being expanded to permit still more magnesium parts to be produced.

*Supervisor, Metallurgical Dept., AC Spark Plug Div., General Motors Corp., Flint, Mich.

Development Program

Our primary objective was to evaluate magnesium die castings from an engineering viewpoint; secondly, we wished to determine whether the metal could be cast into complex parts.

To obtain sample parts for testing, existing dies for zinc-base die castings were converted for casting magnesium on the cold chamber machine. With these, castings for fuel pumps, speedometers, vacuum pumps, oil filters and ornaments were made and evaluated. We subjected these castings to various tests (these tests being dictated by the use of the casting) which included pressure tightness, strength, wear resistance and corrosion resistance under various conditions. Some parts were also tested in service.

Up to this point of the investigation the work was done under more or less laboratory or pilot line conditions. In many instances, we used makeshift tooling. Casting runs were short and production rates were not important. The results of the program, however, in addition to the evaluation of the various castings, pointed out four items of interest: *(a)* Magnesium alloy (AZ 91 B) solidifies rapidly; *(b)* for castings of equivalent volume, the Btu.'s evolved by magnesium and zinc in cooling to the ejection temperature are approximately equivalent, but aluminum evolves considerably more heat; *(c)* magnesium castings are more likely to crack in the die than are zinc castings; and *(d)* the melting, refining and general care of molten magnesium are more critical than for either molten zinc or aluminum.

Table I – Heat Release of Die Casting Alloys

	Zinc Alloy (*a*)	Aluminum Alloy (*b*)	Magnesium Alloy (*c*)
Molten metal temperature	800° F.	1200	1200
Casting ejection temperature	400° F.	600	600
Heat released per cu.ft.	21.5 Btu.	29.2	20.4

(*a*) A.S.T.M. XXIII; (*b*) A.S.T.M. SC 84 B; (*c*) A.S.T.M. AZ 91 B.

Solidification Is Rapid

The heat of fusion of magnesium is lower than that of either zinc or aluminum. This, along with the high-temperature head between the molten magnesium and the steel with which it comes in contact, causes the magnesium to solidify rapidly. Thus, to produce sound castings with a good finish, time for metal transfer from furnace to die cavity should be as short as possible. This can be achieved by using a hot chamber die-casting machine (or automatically feeding molten metal to a cold chamber machine), and by designing dies with shortest possible runners. Also, castings should be designed with a minimum of thin sections, avoiding drastic changes in wall thicknesses.

Before being removed from the mold, the die castings must be cooled to a temperature at which the metal is strong enough to resist bending from the force of the ejection. In cooling, a quantity of heat is given up, most of which is absorbed by the die. To maintain equilibrium conditions, this amount of heat must be removed from the die before the next cycle begins. Therefore, the less heat released, the faster the casting rate.

Table I shows the comparison of heat released from zinc, aluminum, and magnesium under typical operating conditions. Actual operating conditions will alter these figures somewhat, but it can be seen that the heat released by zinc and magnesium is of the same order, while aluminum gives off somewhat more heat. Likewise, the casting rates for zinc and magnesium are comparable, and both can be cast faster than aluminum.

Magnesium castings are more likely to crack before being ejected from the die than are either aluminum or zinc castings. However, generous fillets, radii, and draft will reduce the cracking tendency, and optimum casting and die designs will overcome the problem.

Melting Needs Safety Control

One of the biggest handicaps in starting a program of this sort is the natural fear that most people have of magnesium. So much has been written about the dangers of this metal when in either the molten or finely divided solid state that the unacquainted are afraid to handle magnesium in *any* shape or form. Actually, with a few simple precautions, magnesium is as safe as most other metals. The only difference between the handling of magnesium and the other die-casting metals is that the latitude for error is less.

As for handling hints, it is important to clean the molten metal properly and exclude air by using a protective atmosphere or flux covering. Crucibles should be inspected regularly, and the floor of the combustion chamber should be cleaned frequently (to prevent molten magnesium from coming in contact with scaly iron oxide).

Where finely divided particles of magnesium are generated, the area and equipment should

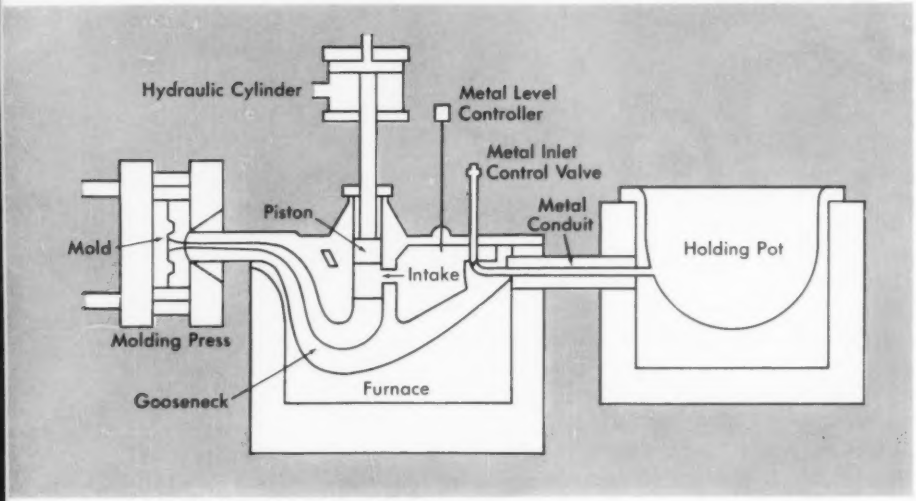


Fig. 1 – Diagram of Hot Chamber Die-Casting Machine. While results were good, maintenance was difficult because the shot system was constantly subjected to 1200° F. heat

be cleaned often to prevent a large accumulation of magnesium. Magnesium chips and powder should be stored in covered steel containers until they are properly disposed of.

(Here it might be noted that the economics of magnesium die casting is complicated by two factors. First, a relatively large amount of flux – on the order of 5 to 10 lb. per 100 lb. of castings – is used. Also, metal loss is higher; two or three times that usually experienced in zinc or aluminum die casting.)

We Go Into Production

Since the results of these tests indicated that magnesium could be used for many automotive applications, AC Spark Plug decided to go further with this program. We went into production on several magnesium fuel pump and oil filter castings, and, at the same time, continued with investigation and development to determine the optimum production equipment and processing methods.

We decided, on the basis of what we already knew, that the die-casting machine should be capable of a fairly rapid cycle. To minimize temperature variations in the metals entering the die cavity, we also contemplated either a means of feeding molten metal automatically to the cold chamber machine, or a change to the hot chamber type machine. Though no method for feeding molten magnesium automatically was commercially available at that time, Dow Chemical Co. did have a hot chamber die-casting machine. When Dow licensed several machine builders to produce this type of machine, we purchased five of these units. These machines, which are diagramed in Fig. 1, produced magnesium castings successfully for several years. However, the costs of maintenance and downtime (caused by the high temperature – 1200° F. – to which the shot system was continually subjected) were deemed too high.

When Dow announced that it had a metering unit which would automatically ladle magnesium into the shot sleeve of a cold chamber machine, we decided to try this approach. A unit of this type (see Fig. 2), put into production in the early part of 1958, has been successful. The advantage of high-speed operation was retained with the added benefits of increased injection pressure, reduced maintenance costs, and lowered expenses for expendable tooling. As a consequence, the hot chamber die-casting machines previously purchased for magnesium casting have now been converted to cold chamber machines which are being used with metering units.

We are now investigating the feasibility of feeding magnesium into the cold chamber sleeve by vacuum (see Fig. 3). Preliminary tests show that this can be done, but it remains to be seen whether or not vacuum feeding offers any advantage over the gravity systems of metering magnesium.

In the future, much larger and more complex castings are being contemplated, and serious thought is being given to the production of ornamental castings. The boundaries of this area are yet to be determined.

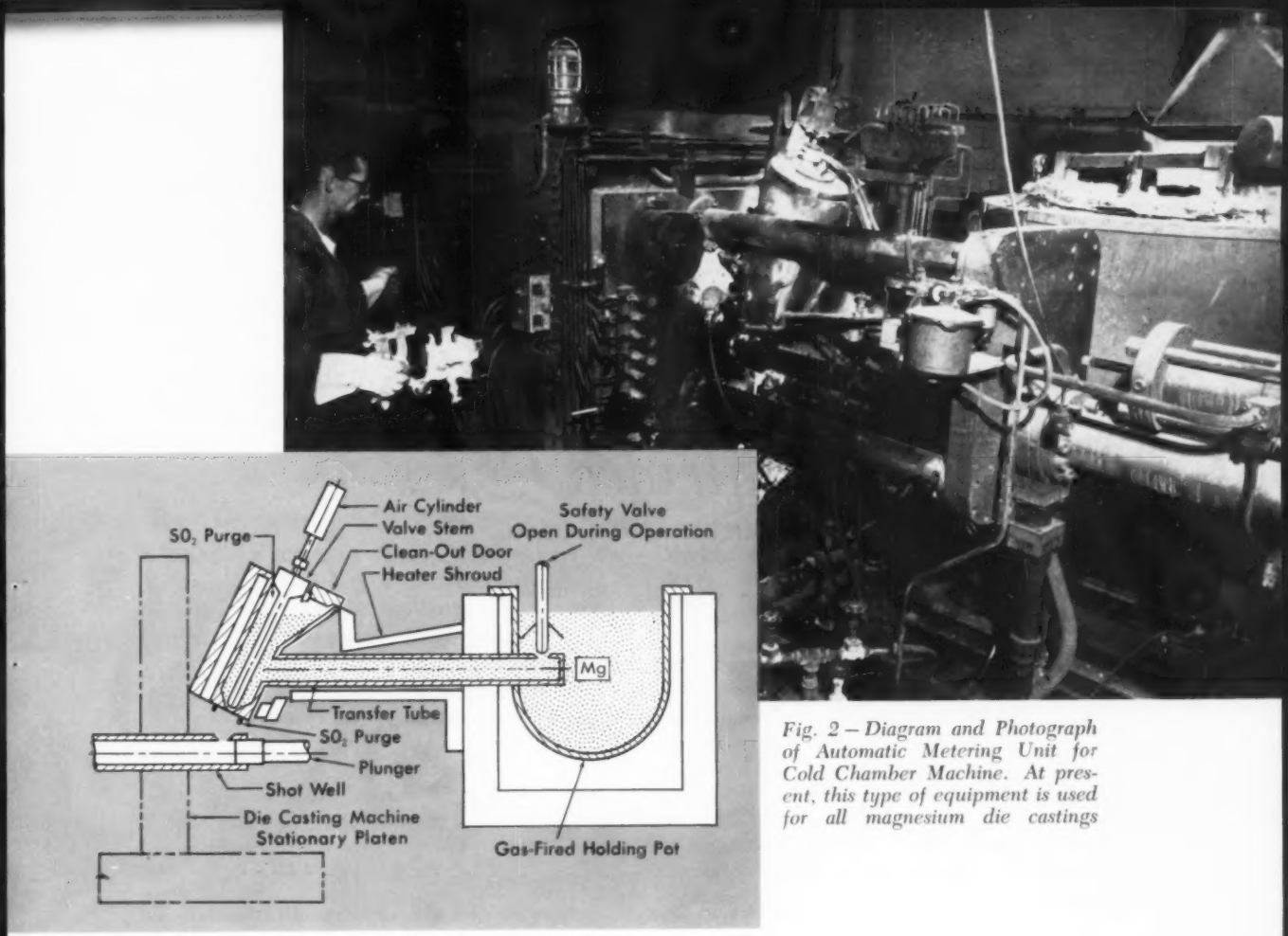


Fig. 2 – Diagram and Photograph of Automatic Metering Unit for Cold Chamber Machine. At present, this type of equipment is used for all magnesium die castings

Fig. 3 – Cold Chamber Machine With Vacuum Feed Unit

Structure of Carburized and Carbo-Nitrided Cases

*By S. R. ROUZE and W. L. GRUBE**

Extensive studies of case hardened steels with the electron microscope have revealed three types of surface conditions – normal, overcarburized, and decarburized. Each type is described, and its characteristics explained. (M27, J28g, J28m; AY)

THOUGH MANY RESEARCHERS† have done much excellent work in identifying the constituents of carburized and carbo-nitrided cases, the exact identity of some of the microconstituents, especially those near the surface, still remains ill-defined. This identification is important since the relationships between structure, residual stress, and the mechanical performance of carburized cases can only be clearly understood when all the applicable data are known. To solve the structure problem, it is thus imperative that these hardened cases be examined at higher magnifications with the electron microscope so that these subsurface microconstituents can be adequately resolved.

This paper discusses electron metallographic studies conducted on a series of carburized and carbo-nitrided steels. Our results support the contentions (predicted by X-ray diffraction‡) that abrupt, unexpected changes in chemistry sometimes occur in the surface layers of production carburized parts. These changes in chemistry, in turn, cause low-strength microstructures to appear in the surface layers. How these low-strength microconstituents at the surface might influence quench cracking, grinding cracking, and, ultimately, the mechanical performance of the case hardened part is also considered.

*Physicists, Research Laboratories, General Motors Corp., Detroit.

†"Structure and Properties of Some Carbo-Nitrided Cases", by K. B. Valentine, *Metal Progress*, Vol. 63, June 1953, p. 97; "The Heat Treatment of Mild Steel in Raw Town Gas and Ammonia Atmospheres", by M. A. H. Howe and E. Mitchell, *Journal* of the Iron and Steel Institute, Vol. 187, Part 3, November 1957.

‡"The Distribution of Residual Stress in Carburized Cases and Their Origin, by D. P. Koistinen, *Transactions*, American Society for Metals, Vol. 50, 1958.

Case Hardening the Specimens

To provide a variety of cases for examination, several types of steel were obtained, and were case hardened by a number of different treatments. Most of the specimens were then mechanically polished and etched in nital or nital-containing zephiran chloride. The replica used with the R.C.A. EMU-2A electron microscope was Formvar plastic negative shadowed with chromium, or a preshadowed carbon positive. The wide variation in structure from case to core in the S.A.E. 1018 and S.A.E. 8620 steels made it necessary to employ a different

etchant (picral) to develop the mixed structure in the soft cores of these steels.

Microhardness measurements were made on cross sections of the cases with a Bergsman microhardness tester (static load 100 g.). For maximum reproducibility, the rate of loading was made the same for all measurements, the load being applied by driving the fine-focus screw of the microscope with a constant speed motor. The load was held 15 sec.

Diamond pyramid hardness was calculated, and converted into Rockwell C hardness.

Three Conditions Are Observed

Hardness data and electron micrographs of the case and cores revealed three types of conditions. These are: *(a)* normal case microstructure on carburizing steels, *(b)* cases with "over-carburization" at the surface, and *(c)* cases with decarburized surface layers.

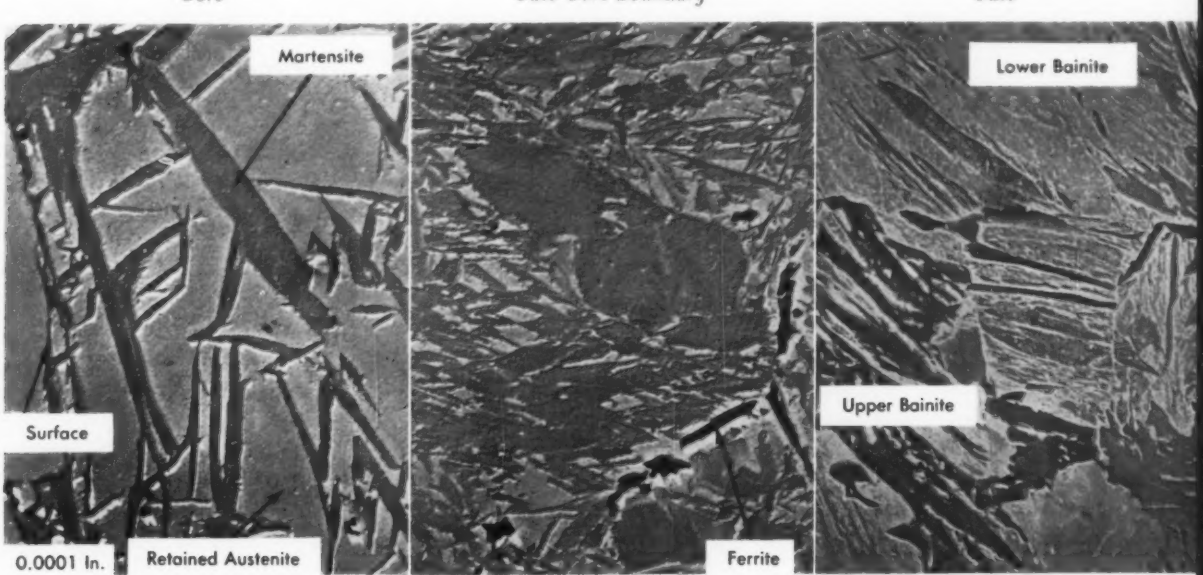
Figure 1 shows three electron micrographs representative of normal microstructure throughout a case on S.A.E. 1132 steel. This case is considered "normal" because the martensite-retained austenite structure extends completely to the heat treated surface. Although it may appear that there is an unusually large percentage of retained austenite at the surface to consider this a "normal case", the amount observed is not regarded as abnormal considering the temperature of the quench (350° F.). In fact, when some of the tested steels were quenched to 350° F., considerably more than 50% austenite was retained.

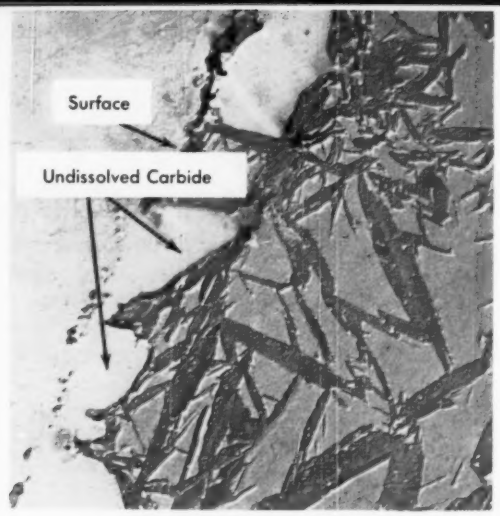
Near the case-core boundary, transformation to martensite is more complete, but the quenching rate is too slow to avoid forming some proeutectoid ferrite at the austenite grain boundaries. The core structure of this steel contains both upper and lower bainite but is predominantly lower bainite. This accounts for the reasonably high hardness (above Rockwell C-50 in the core).

"Over-Carburization", the Second Condition

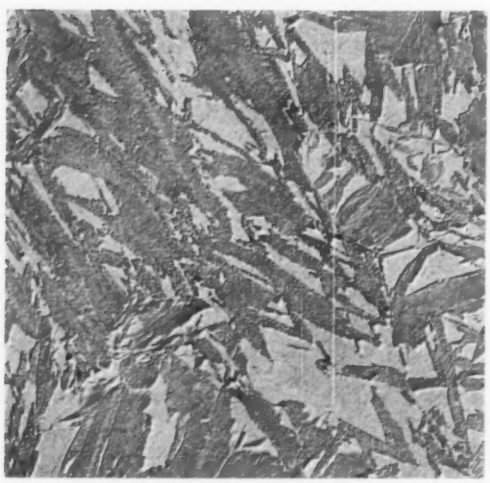
Over-carburization is defined, in this work, as that carbon content which results in the formation of undissolved carbide in the surface layers. These carbides are not a surface scale or film, but clearly lie beneath the surface of the steel, as indicated in Fig. 2 (top). It should be pointed out that this condition is not unusual but often occurs in production. In fact, the condition is sometimes produced intentionally with the idea in mind that a suitable case depth can be obtained more quickly and that no damage will be done because the "over-carburized" surface layer will be removed in finishing. However, the part might still perform

Fig. 1 – This Is Considered to Be a Normal Microstructure. Though much retained austenite is present at the surface, the quenching temperature (350° F.) is such that this condition is not thought to be unusual. A "normal" case has the martensite-retained austenite structure out to the surface

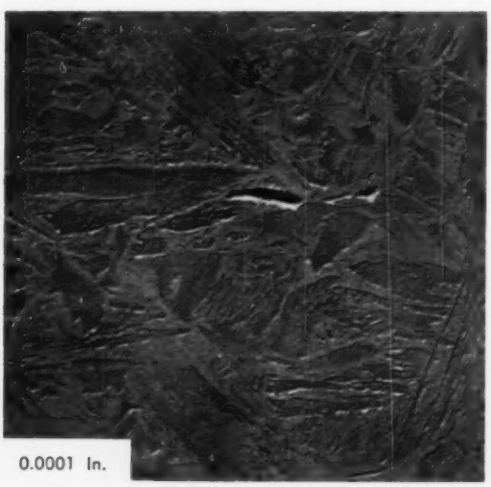




Case



Case-Core Boundary



Core

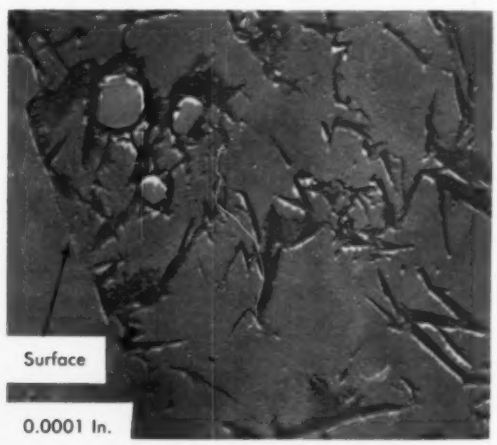
Fig. 2 – An "Over-Carburized" Condition Is Illustrated by This Series. Note the undissolved carbides just beneath the surface, and the martensite-austenite structure of the core

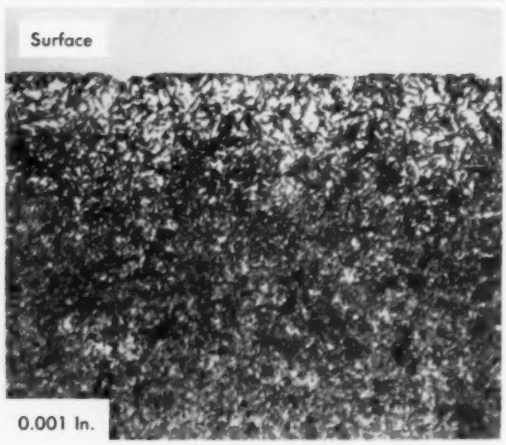
poorly if this surface layer is not removed from all highly stressed areas.

The effect of over-carburization is illustrated by the other micrographs in Fig. 2. Even though this steel was quenched directly to 130° F., large amounts of austenite are retained in the case structure. These micrographs also indicate that the martensite-austenite structure continues into the core of this steel, core hardness being above Rockwell C-60.

Figure 3 shows the microstructure (by electron and light microscopy) at the surface of an over-carburized S.A.E. 1340 steel. While the amount of martensite could be increased by quenching directly to a lower temperature than that employed for this specimen (350° F.), very little martensite is formed in cases contain-

Fig. 3 – An "Over-Carburized" Case Containing Undissolved Carbides as Shown by Electron (Top) and Light Microscopes (Bottom). Clearly, the "white constituent" seen under the light microscope is retained austenite





ing nitrogen when carbon is high enough to result in undissolved carbides. When such a small amount of martensite is present, it is often difficult to determine the exact nature of the microstructure at the surface under the light microscope. However, the electron microscope clearly shows that the light areas near the surface are extensive regions of retained austenite which contain only a small amount of martensite. It is our belief that, heretofore, austenitic layers at the surface of carburized cases containing nitrogen have often been erroneously labeled as another phase, or the mysterious "white constituent". It has been our experience that the major nonetching phase (with the exception of undissolved carbide) in these carburized and carbo-nitrided cases is always retained austenite.

When the amount of retained austenite reaches such a high level it might be expected to decrease markedly the measured hardness near the surface. However, this may not happen. To show why, an electron micrograph of a hardness indentation made with a light load is shown in Fig. 4. Since most hardness indentations are made with heavier loads, it is evident that the actual impression would span several areas of austenite, and hence would be supported mainly by the martensite matrix. Thus, the measured hardness will be higher than that expected from the large amount of retained austenite present.

Decarburization Also Occurs

The third condition – decarburization – is illustrated in Fig. 5, an electron micrograph of a carburized case on S.A.E. 8620 steel. From a short distance below the surface, and on into the core, the microstructure is chiefly martensite and retained austenite. However, at the surface (and extending down into the speeimen along grain boundaries) evidence of decarburization is shown by the presence of an isothermal transformation product – in this instance, pearlite. This decarburization was detected by X-ray diffraction through a marked decrease in the amount of retained austenite in the surface layers. This indicates that either transformation at the surface had proceeded further toward completion, or that isothermal transformation had occurred. The resulting product depends upon the extent of decarburization. In the present example, an isothermal transformation product was formed.

Decarburization is not uncommon, but occurs quite frequently in practice. However,

Fig. 4 – Hardness Indentation Made With Light Load. Since the usual indentation is made with a much heavier load, it is evident that the resulting impression would span several areas of austenite. The consequence is that hardnesses will be higher than the large amount of retained austenite would lead one to believe

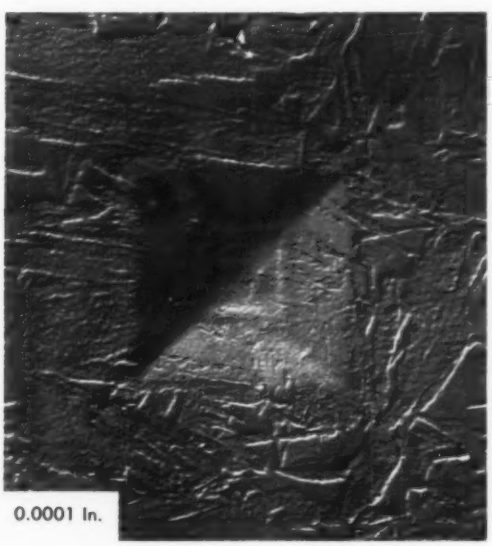
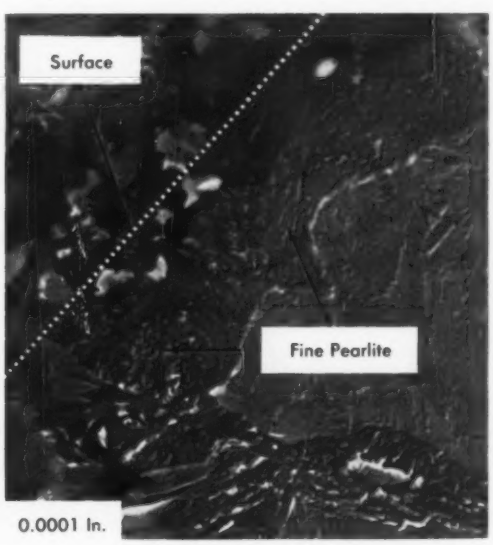


Fig. 5 – Decarburization Is Illustrated Here. Though the microstructure below the surface is chiefly martensite and retained austenite, pearlite at the surface and in the grain boundaries indicates that carbon has been lost. This condition occurs frequently in practice, and may often account for unexplained failures



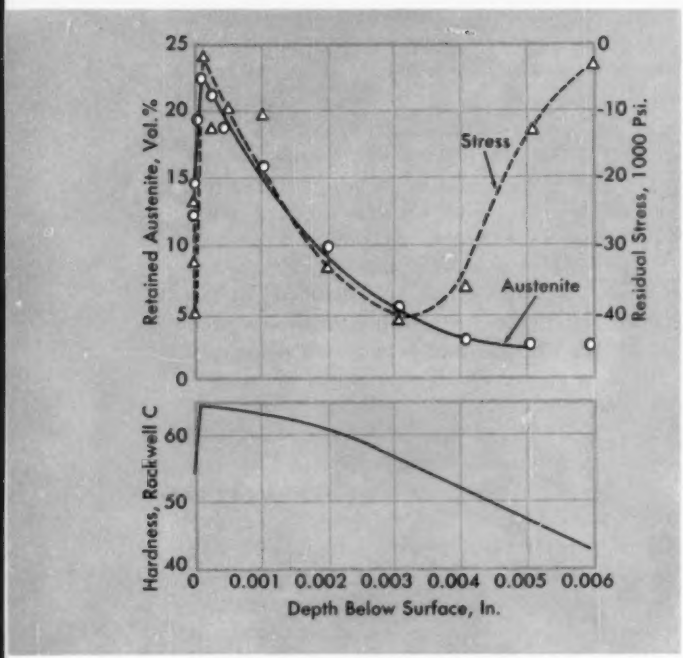


Fig. 6 – Correlation of Hardness, Stress, and Amount of Retained Austenite in a Decarburized Case. All of the variables follow closely with the extent of decarburization

because it is often quite superficial, it goes undetected unless electron microscopy or X-ray diffraction techniques are used. Although decarburized layers are generally very thin, it does not necessarily follow that they are insignificant. How these layers might influence the performance of a carburized part is illustrated by Fig. 6.

When the residual stress distribution through the carburized case is plotted against depth, a close correlation between the stress distribution and the amount of retained austenite present is observed down to the point of maximum compressive stress. In the surface zone, the decrease in retained austenite, and the resultant increase in residual compressive stress, is due to partial decarburization. Although the stress is highly compressive at the surface, the abrupt reversal at 0.002 in. (plus the relatively weak surface microstructure) could easily wipe out any desirable effect the residual compressive stress might have on fatigue life. Nor would removing this 0.002 in. necessarily improve the situation. If the metal were ground off or worn away, there would be a marked change in the magnitude of the residual compressive stress at the surface.

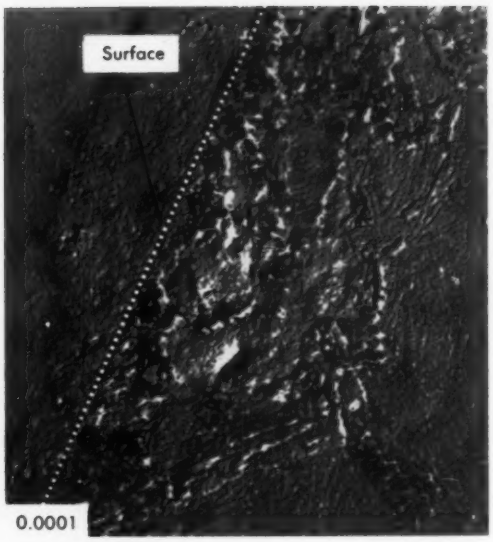


Fig. 7 – Electron Micrograph of Fillet Area in Carburized Gear Which Broke in Service. Deep etching indicates that the area was decarburized

An instance in which a decarburized surface layer may have influenced the mechanical properties of a carburized part is illustrated by Fig. 7. This electron micrograph shows the cross section at the surface in the fillet area of a carburized pinion gear of A.I.S.I. 4817 steel. During service, several teeth of this gear broke in the fillet area. The micrograph shows that there is a deeply etching phase at the surface, thus indicating that decarburization had occurred. In this instance the part failed where a decarburized layer is present.

In Conclusion

From these electron metallographic studies it is evident that abrupt, unexpected changes in microstructure often occur in the surface layers of carburized and carbo-nitrided parts. This micrographic evidence supports previous X-ray diffraction studies. It is our belief that, heretofore, many changes in the structure of thin surface layers have gone undetected. Also, some of the anomalies encountered in the mechanical performance of carburized and carbo-nitrided test specimens and production parts may be explained by the presence of these unexpected, yet frequently occurring, microstructural changes.

Constricted-Arc Process Cuts Metals Under Water

*By C. H. WODTKE**

Constricted-arc cutting with torches of special design has been adapted at Oak Ridge National Laboratory for underwater operation and is being used successfully in the maintenance of nuclear reactors. Cutting is rapid and because the torch and work are completely submerged, spatter is confined and release of radioactivity to the air is reduced to a safe level. (G22)

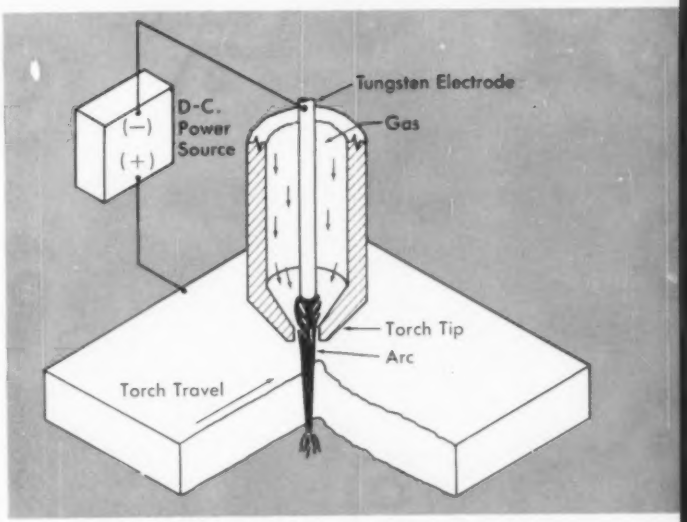
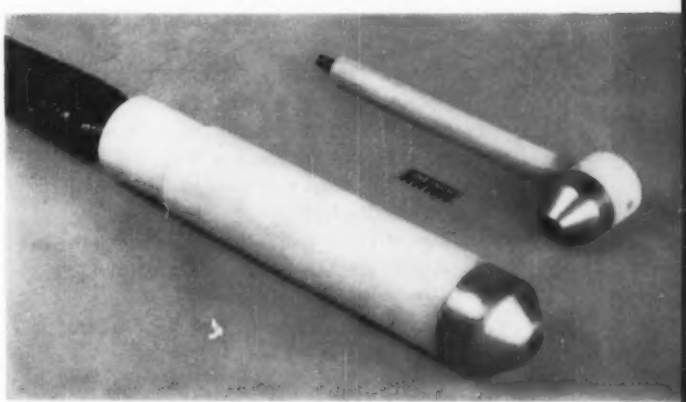


Fig. 1 – Basic Features of Constricted-Arc Cutting. Inert gas, heated by the arc, is greatly expanded and ejected at high velocity

Fig. 2 – Special Constricted-Arc Torches for Underwater Cutting. Torch bodies and cutting tips are copper; insulating jackets are nylon



THE CONSTRICTED OR PLASMA ARC has been a tool for cutting metals since the introduction of commercial equipment in 1955. Basic features of the process, shown in Fig. 1, include an inert-gas stream, and a direct-current arc from the tungsten electrode which pass through a constricting orifice to the work. Heated and greatly expanded by the arc, the gas is ejected at high velocity. The concentrated heat and jet-like action result in rapid melting and removal of the base metal.

Although available equipment is designed for operation in air, early work by the manufacturer indicated that the arc could function with the tip of the torch submerged in water. For maintenance work on nuclear reactors, underwater cutting in which the entire torch is submerged offers particular advantages. When repairs are required, water is often used as a shielding medium to reduce the hazards to workmen and to prevent any possible spread of radioactivity.

*Metallurgist, Metallurgy Division, Oak Ridge National Laboratory. (Operated for the U.S. Atomic Energy Commission by Union Carbide Nuclear Co.)

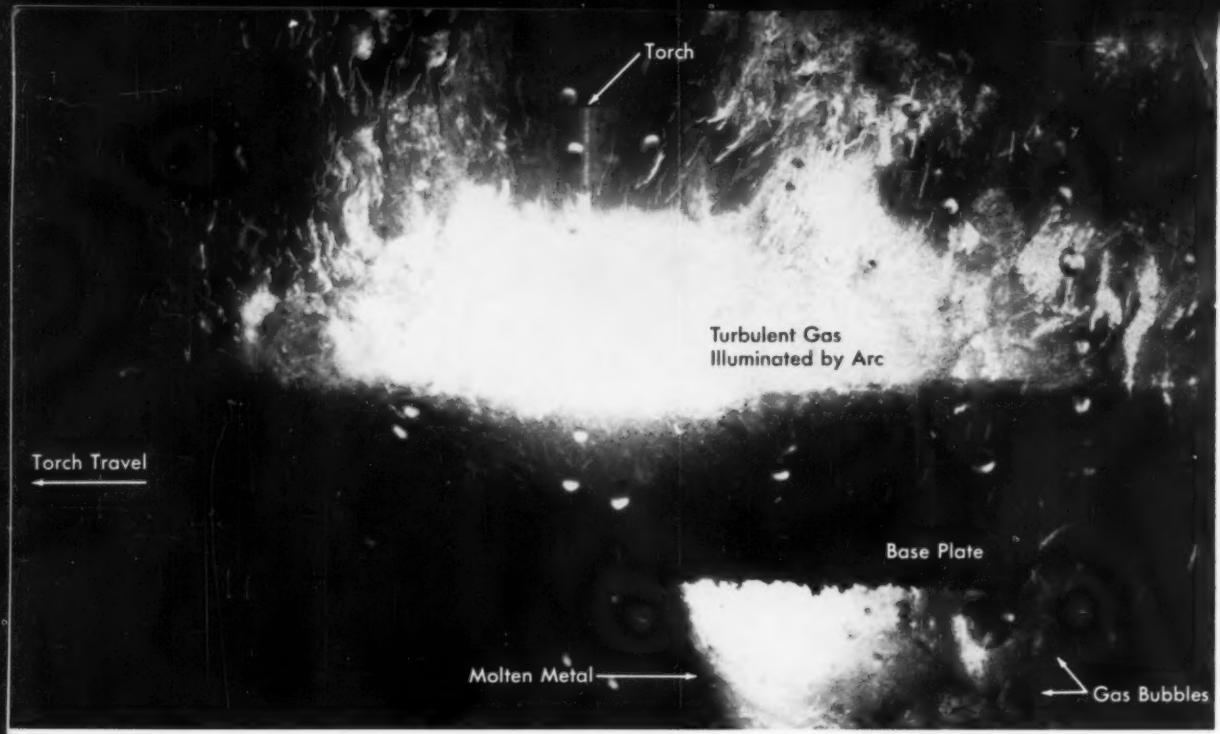


Fig. 3 – Underwater Cutting of a 1-In. Stainless Steel Plate With Large Torch. While limiting the spread of radioactivity when cutting radioactive materials, water also prevents damage to nearby components by quenching the stream of molten metal

Table I – Typical Underwater Cutting Conditions

Base Plate	Speed	Current*	Argon Flow
	Small Torch†		
⅜-in. stainless steel	60 in. per min.	400 amp.	100 cu.ft. per hr.
½-in. stainless steel	20	400	100
3/16-in. aluminum	150	400	100
⅜-in. aluminum	80	400	100
¼-in. Zircaloy-2	40	400	100
	Large Torch†		
1-in. aluminum	35	620	465‡
1-in. stainless steel	30	650	465‡
1-in. carbon steel	25	600	465‡

*Direct current, straight polarity at about 84 volts.
†Torch is shown in Fig. 2, p. 91. ‡At 40 psi.

In adapting the constricted arc to underwater cutting in reactors it was necessary to design and build the special torches shown in Fig. 2. The smaller of the two resulted from experimental work aimed at producing a small, simple torch for use in a reactor core vessel. The large torch was built for underwater cutting of thick sections where access to the work was not restricted.

Still undergoing development, the torches and associated controls differ significantly from commercial equipment. No internal cooling water is provided. The arc can be started with the torch submerged, using high-frequency current alone. Argon, flowing at a rate of 5 cu.ft. per hr., keeps water out of the torch and thereby decreases electrode deterioration. In most instances argon is used as the cutting gas.

For operation of the small torch, a pair of 300-amp. d-c. rectifier welders is connected in series and generally adjusted to maximum output. As shown in Table I, cuts have been made in various materials up to ½ in. thick at 20 in. per min. Maximum water depth during cutting has been about 30 in.

Torch motion is always started with the torch off the plate. Then with the torch traveling at cutting speed, the arc is self-initiated and the kerf forms without necessity for a pause.

Power to the large torch is supplied by 3 pairs of 300-amp. d-c. rectifiers connected in parallel. As shown in Table I, cuts have been made in various metals up to 1 in. thick. Water depth during cutting has been 12 in. When cutting plate as thick as 1 in., the arc is started and the kerf formed while the torch is moving at full cutting speed. Figure 3 pictures the large torch cutting 1-in. thick stainless-steel plate underwater at about 15 in. per min.

Typical cuts in 1-in. aluminum, stainless

steel, and carbon steel plate are shown in Fig. 4. The large torch was used here. The width of the cut varies only slightly with material; it is just under ⅜ in. on the arc side, narrowing to ⅛ in. on the under side. In aluminum the cut is essentially slag-free on the underside, but the face is oxidized and rough. Cuts made in stainless steel have a little attached slag, which is normally easily removed, and only slight oxidation and roughness on the cut face. In carbon steel the cut face is quite smooth with only a thin oxide film; a sharp edge is exposed when the resolidified metal and slag from the kerf are broken off.

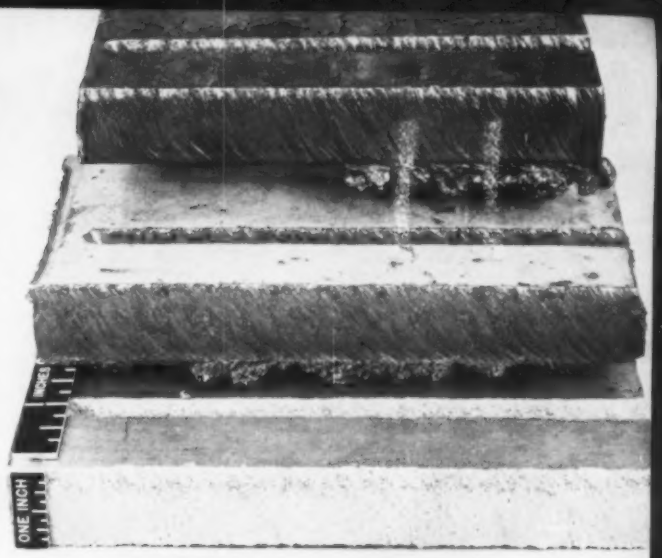


Fig. 4 — Underwater Cuts Made With Large Torch Shown in Fig. 2. Top: Carbon steel (part of the slag has been removed); center: Type 304 L stainless (as cut); bottom: 1100 aluminum (as cut). All plates are 1 in. thick

Solves Problem in Reactor Maintenance

In recent maintenance on the Homogeneous Reactor Experiment (HRE-2) at Oak Ridge National Laboratory it was necessary to remove from inside the highly radioactive core vessel several perforated diffuser plates of Zircaloy-2. The plates, which are ⅛ in. thick and about 18 ft. below the work level, could be reached only through a single access port having a 2-in. diameter restriction. Removal of the plates required that they be reduced in size to pass through the same hole. Thermal cutting seemed more readily adaptable to the problem than did mechanical cutting provided that adjacent components would not be damaged by the arc or by molten spatter. Laboratory work showed that underwater cutting was practicable, and that the water restricted spatter travel within safe limits. To overcome access limitations, it was necessary to produce a simplified, miniature cutting torch like that shown in Fig. 2. A similar torch, attached to a unique manipulating device (developed by reactor maintenance personnel) to permit remote operation, was used to cut the diffuser plates within the reactor core vessel into strips which would pass through the access port.

Alteration of a structural member in a reactor cell is another cutting operation planned for the near future. For shielding during general maintenance on HRE-2, one or more of the cells which contain the components of the reactor system are flooded. Many mechanical operations are then performed by means of long-handled tools. To rearrange a component, a portion of the ⅞-in. thick flange of a steel H-beam located 10 ft. underwater must be removed. The cut will be about 40 in. long. It is anticipated that the large constricted-arc torch shown in Fig. 2 can be used.

Potential Applications

It appears that constricted-arc cutting could be extended by adaptation for underwater use to many new applications. As work at O.R.N.L. has shown, underwater cutting may be necessary or desirable for construction, maintenance, or scrapping operations on reactors or processing systems in nuclear energy plants. Thermal cutting could be performed on components contaminated by radioactivity, such as vessels, piping, and fuel assemblies while submerged in water for shielding. Special torches in various sizes and shapes could be readily made and adapted to remote operation and to other individual job requirements. Turbulence of the water during cutting washes the gas and the molten and oxidized metal. This helps trap fine particles and reduces the spread of radioactive residues to the air. The water will quench the spatter, and thus may prevent damage to other components.

In other areas, the use of submerged constricted-arc cutting might help solve similarily difficult problems. Cutting in liquids other than tap water may be practicable. When preparing metals for fabrication, the cooling action of the water would aid in limiting the depth of heat-affected zones. Time required for final cleanup might thereby be reduced. An advantage might be realized in preventing a change in crystal structure during rough preparation of specimens before metallographic examination.

These Two Astroloy Forgings Were Produced on Wyman-Gordon Co.'s 35,000-Ton Closed-Die Forging Press. The turbine wheel with the integral shaft weighs 20 lb. while large disk weighs well over 100 lb. Parts weighing up to 1000 lb. and 35 in. in diameter are now being forged

Astroloy—a Superalloy for 1900° F. Use

*By J. F. BARKER, W. H. COUTS, Jr., and R. J. MORRIS**

This latest nickel-base superalloy contains, among other alloying elements, 4.5% aluminum, 3.5% titanium and 0.03% boron. It has excellent yield strength and stress-to-rupture properties, and can be readily shaped and welded while in the annealed condition. These properties are expected to make the alloy useful in jet engine components such as turbine blades. (A-general, Q-general, J-general; Ni-b, SGA-h)

ASTROLOY, THE LATEST SUPERALLOY to come out of the Flight Propulsion Div. laboratories of General Electric, is a vacuum melted, precipitation hardening, nickel-base alloy which is strengthened by coherency of the familiar $Ni_3(Al, Ti)$ compound. Its excellent strength-weight ratio (see Fig. 1) makes it useful for parts in jet engines designed for supersonic flight and other advanced propulsion systems.

One may well ask "Why, with so many other superalloys available, was *another* one necessary?" Well, certain zones in the new supersonic engines demanded structural materials which could operate in the 1800 to 2000° F. range in oxidizing environments while under substantial loads for considerable periods. Because some components would also have to be fabricated of sheet, the high strength would have to be achieved by solution and aging heat treatments. Another essential, oxidation resistance, could, of course, be supplied by one of several commercial coatings. However, cost could be kept lower if the alloy itself possessed inherent oxidation resistance.

Decidedly, the nickel-base type of alloy offered more promise than cobalt or iron bases.

*Mr. Barker and Mr. Couts are with the structural Materials Unit, Metallurgical Engineering, Jet Engine Dept., Flight Propulsion Div., General Electric Co., Evendale, Ohio. Mr. Morris, formerly Advanced Engineering, Rocket Engine Section of General Electric in Evendale, is now with International Nickel Co., Dayton, Ohio. The authors wish to thank John Radavich for furnishing the electron photomicrographs.

Concerning the alloying elements, previous work on DCM and René 41 (both nickel-base), together with the myriad of papers in the literature, indicated that higher aluminum and titanium levels were called for. Likewise, a judicious amount of boron would undoubtedly enhance high-temperature rupture strength.

While we could set the carbon, molybdenum, chromium, aluminum, titanium and boron levels fairly well (by extrapolating previous experience), we believed that cobalt would be a critical element. In fact, cobalt was considered to be the "keystone" of the chemical composition needed to provide high strength along with acceptable producibility, fabricability, and oxidation resistance. Therefore, to ascertain this optimum cobalt level, four slab ingots, each weighing 10 lb., were vacuum induction melted with nominal levels of 5, 10, 15 and 20% cobalt. By testing 0.065-in. sheet rolled from these heats, we found that their mechanical properties were generally superior to those of existing sheet alloys. Also, as the cobalt level increased, hot workability, rupture strength, and formability improved, but the tensile strength declined. In the 20% cobalt alloy, oxidation resistance at 2000° F. was poorest; however, for the other three this property was excellent.

The improvement in mechanical properties at elevated temperatures was attributed to the increased aluminum level and the higher γ' (gamma prime) solution temperature.

After much research into property variations, we decided to retain the basic composition, choosing 15% as the optimum cobalt level. Nominally, this nickel-base alloy was 0.5% C, 4.50% Al, 3.50% Ti, 5.00% Mo, 15.00% Cr, 15.00% Co, 0.05% Si, 0.05% Mn and 0.03 B. As an incidental advantage, the higher aluminum level caused a decrease in the density to 0.287 lb. per cu.in. for Astroloy versus 0.297 lb. per cu.in. for René 41.

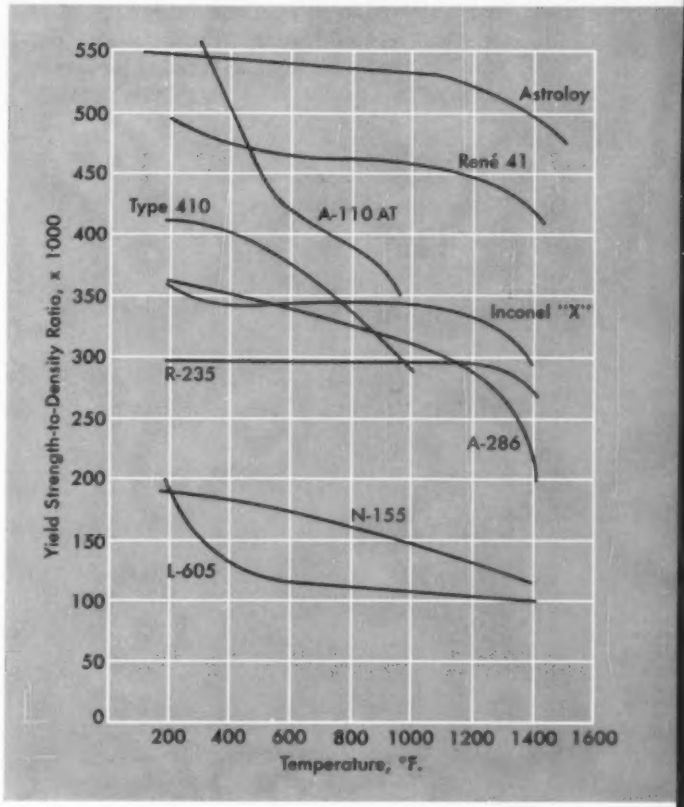


Fig. 1 — Strength-to-Density Ratio of Astroloy Compared to That of Several Other Superalloys. The Astroloy curve has been obtained from 0.060-in. sheet which has been heated at 2100° F., held for 30 min., air cooled, heated at 1400° F. held for 16 hr., and finally air cooled again

Sheet Rolled in Production

To date, several thousand pounds of finished Astroloy sheet have been produced by rolling vacuum induction melted slab ingots (weighing up to 500 lb.) directly on hot mills. Shrinkage, which caused some difficulties at first, was eventually eliminated by closely controlling the melting and pouring practices.

For best results, the ingots are homogenized at 2100° F. and hot worked in the 1950 to 2050° F. range. Because the working range is narrow the soaking furnaces must be near enough to the rolls so that a minimum of heat is lost when the slab ingots are transferred to the mill. (In actual practice, as many as four passes could be made per heating by transferring the ingot within 10 sec.) Though initial reductions are light, they can be increased to around 15% when the ingot has been sufficiently worked.

Astroloy is cold rolled in a manner similar to that for other superalloys. Only a small amount of reduction per anneal is possible due chiefly to the high annealed hardness, Rockwell C-35. Astroloy sheet has been produced in thicknesses between 0.030 and 0.090 in. in strip 36 in. wide by 96 in. long. Narrow strip, 0.001 in. thick, has also been produced.

Due to its inherent high strength, Astroloy is difficult to form into useful hardware. Exhaus-

tive tests to find an optimum annealing cycle – one which would promote softness and ductility and still be feasible from a production standpoint – finally resulted in the following treatment. In brief, the stock is heated to 2100° F., held 30 min., air cooled, heated to 2000° F., held 15 min. and water quenched. While this may appear to be a most unconventional annealing cycle, it can only be argued that it works. (As a cautionary note, Astroloy sheet cannot be water quenched safely from above 2075° F., the solution temperature.) When mill annealed in this manner Astroloy sheet has a tensile strength of 178,000 psi., a yield strength (0.2% offset) of 123,000 psi., and an elongation of 22%. (These and other figures are averages from four production heats.) The sheet will bend to a minimum radius (90° bend) of 0.090 in., and the depth of draw (Erichsen cup test) is 0.250 in.

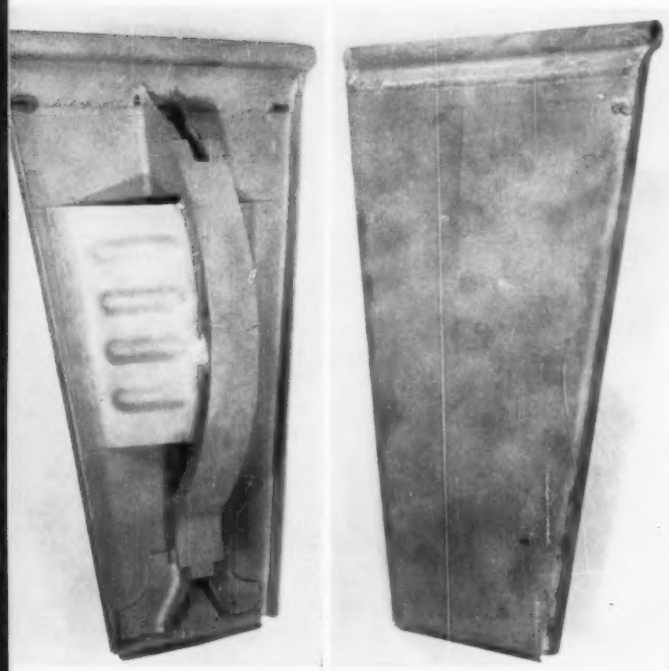


Fig. 2 – Top and Bottom View of Engine Flaps Made of Astroloy. This part was made up from sheet sections and castings which were welded together while in the annealed condition. Heat treatment for improving stress-to-rupture strength followed fabrication

Fig. 3 – Representative Castings of Astroloy

For maximum creep-rupture strength in the 1400 to 1800° F., range, solution at 2100° F. for 30 min., and air cool; then age at 1650° F. for 4 hr. Air cooling completes the cycle.

Properties which result from such treatment –they represent averages from four production heats (0.060-in sheet) – are as follows:

Tensile Properties	Temperature Room	1400° F.
Tensile strength	194,000 psi.	155,000 psi.
0.2% yield strength	142,000	139,000
Elongation	15.0%	6.0%
Stress-Rupture Properties	**Temperature 1650° F.**	**1800° F.**
Stress	27,000 psi.	18,000 psi.
Time to failure	177.0 hr.	50.7 hr.
Elongation	8.0%	7.0%

Thermal cycling data indicate that cyclic exposures to temperatures higher than the aging temperature are not detrimental to tensile strength, rupture life, or ductility. These data were obtained from test specimens which were thermally cycled ten times, being heated and cooled (each time between 1350 and 1875° F.) within 30 sec. to simulate the rapid changes that occur in gas turbine engines. After this treatment, the tensile strength (at 1400° F.) was 145,000 psi., the yield strength (0.2% offset) was 124,000 psi., and the elongation was 11.1%. (These figures are averages of three tests.) The control had equivalent results slightly below the average reported in the previous paragraph.

That Astroloy can be fabricated is demonstrated by the jet engine flap show in Fig. 2. To make this item, sections were formed from sheets in the annealed condition (Rockwell C-36). They were then assembled by inert-arc fusion and resistance welding, Hastelloy "X" wire being used as the filler. To eliminate

strain age cracking (which can occur upon heat treatment after welding), the welds were hammer peened before solution treatment and again before aging. High electrode pressures, about 4000 lb., were required for sound spot welds; otherwise nugget porosity and metal expulsion resulted.

Investment Castings

Although originally developed as a wrought alloy, Astroloy has also been satisfactorily cast into complex shapes with little difficulty, as Fig. 3 illustrates. When several heat treatments were investigated for the cast alloy, test results indicated that the optimum combination of rupture life and tensile properties was obtained by solution treating for 2 hr. at 2100° F., followed by air cooling. Typical stress-rupture and tensile data (obtained on 0.252-in. diameter cast-to-size specimens with the above heat treatment) are presented below:

STRESS RUPTURE RESULTS at 1800° F.

STRESS	LIFE	R.A.
20,000 psi.	78.7 hr.	4.7%
20,000	130.1	5.6
22,000	31.3	5.0
22,000	39.7	7.0

As heat treated, Astroloy contains four phases – and a fifth one will form after service exposure in the 1700 to 1900° F. range. Appearing in the mill-annealed structure (Fig. 4) are the gamma or austenitic matrix, the gamma-prime precipitate, titanium carbides, and a boride (M_3B_2). This sample was annealed for 30 min. at 2100° F., air cooled, heated 15 min. at 2000° F., and water quenched. The γ' precipitate, which gives the alloy most of its strength, dissolved between 2050 and 2075° F. but the TiC and most of the M_3B_2 remain undissolved. Some of the γ' was precipitated and agglomerated during the 2000° F. cycle. Though this treatment reduces the supersaturation of aluminum so that quenching can be more effective, a fine dispersion of γ' can still be observed.

After fabricating, the sheet is heat treated for 30 min. at 2100° F., air cooled, held 4 hr. at 1650° F., and air cooled again. Figure 5 shows a necklace of borides at the grain boundaries. Aging at 1650° F. precipitates a uniform γ' with some agglomeration of the borides, though the subsurface region may not have any borides if "de-boronization" – the preferential oxidation of boron – has occurred. Since forgings receive a similar solution at 2100° F. and

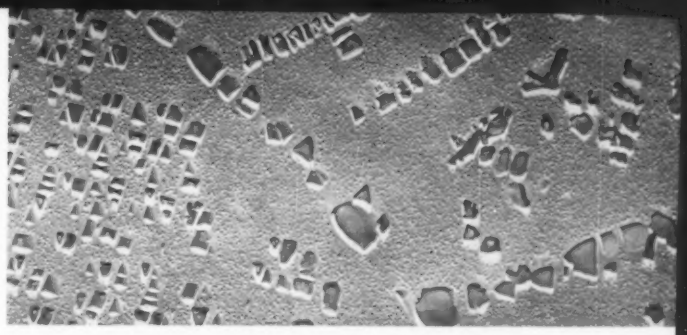


Fig. 4 – Structure of Mill-Annealed Astroloy as Revealed by the Electron Microscope. Four phases are shown, the austenitic matrix, the gamma prime precipitate, titanium carbides, and a boride, M_3B_2

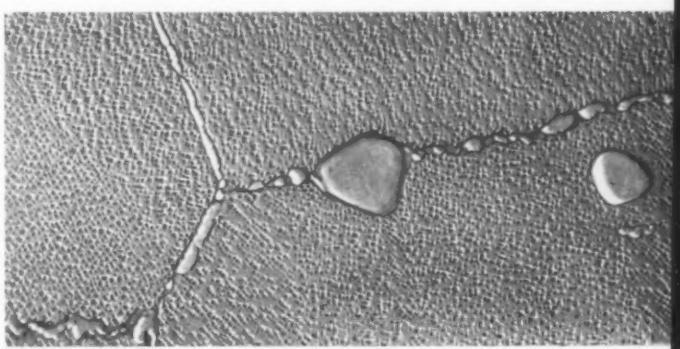


Fig. 5 – Microstructure of Heat Treated Astroloy. The alloy has been heated at 2100° F., held 30 min., air cooled, heated at 1650° F. for 4 hr., and air cooled. This aging treatment precipitates gamma prime uniformly throughout the matrix and agglomerates the borides to a degree. Original magnification, 10,000 ×

are aged at 1400° F. for maximum tensile properties, the only microstructural difference to be expected would be a finer γ' particle size due to the lower aging temperature.

Exposure under stress at temperatures between 1700 and 1900° F. will cause the TiC to decompose and $M_{23}C_6$ to form at the TiC-matrix interface. This reaction does not embrittle the alloy because it is not a grain-boundary reaction.

Astroloy sheet has potential use in lightweight fabricated components that must operate in air under stress in the 1600 to 1800° F. range. Such components would include jet engine primary nozzle flaps, turbine blades, nozzle diaphragm partitions, and springs. The alloy can also be used in turbine blades and hardware-type castings for fabricated structures. As for forgings, Astroloy is being considered favorably for use in jet engine turbine wheels and compressor disks because of its superior microstructural stability at 1400 to 1700° F.

Book Review

Nondestructive Testing— a Complete Survey

*Reviewed by T. W. JUDD**

NONDESTRUCTIVE TESTING HANDBOOK, edited by Robert C. McMaster for the Society for Nondestructive Testing. Ronald Press Co., New York. 1959. 2 Vol. $24.

EVEN THOUGH A LARGE AMOUNT of information on nondestructive testing is available, there has never existed a single comprehensive reference source. Now, at last, that gap has been filled, and we have a handbook which represents the first extensive integration of knowledge of all major phases of nondestructive testing. A monumental achievement in two large volumes, the Nondestructive Testing Handbook should benefit all who have an interest in either the technical or managerial aspects of the art.

Edited by Robert C. McMaster, this handbook was prepared under the auspices of the Society for Nondestructive Testing, with the help of a committee of over 100 contributing editors. (The list of contributors, in fact, reads like an international who's who of distinguished scientists, engineers, and executives in the field.) Because of the large number of participants, readability and quality vary from section to section. However, there is evidence of remarkable cooperation; the authors, for the most part, have confined themselves to their subjects and avoided overlapping of material.

In its two volumes, the book provides adequate discussions and test procedures for solving a large number of nondestructive testing problems. It embraces all the widely recognized fields of nondestructive testing: radiography, electromagnetic, ultrasonic, penetrant, and magnetic particle inspection. In addition, the first five sections – there are 54 sections in the handbook, incidentally – contain basic preliminary information on the general subject of nondestructive testing.

Section I delves thoroughly into the functions of nondestructive testing in modern industry. Here, economic factors are evaluated, the fundamental concepts of quality control are enumerated, and suggestions are given regarding management policies related to testing. Section II covers the setup and operation of testing laboratories, and research and development laboratories. Next, Section III outlines the specialized aspects of field and maintenance testing with subsections devoted to inspections of oil refineries, pipe lines, ships, aircraft, and chemical and industrial plants. In Section IV, the general characteristics of various tests are discussed, including a comprehensive comparison of destructive and nondestructive tests with reference to cost, speed, personnel requirements and other factors. Section V delineates basic test methods in detail. Here, tests have been divided into motion-of-matter, transmission-of-energy, and matter-and-energy groups.

Remaining sections in Volume I describe all aspects of specific tests with penetrant, optical, and radiographic inspection. In Volume II are sections on particle, eddy current, ultrasonic, and miscellaneous tests.

If any criticism can be made, it might be said that the handbook is almost too complete. It also includes sections on the measurement of some phenomena which might more properly come within the scope of other publications. There seems to be room for argument, for example, as to whether or not the measurement

*Project Engineer, Electromechanical Research Center, Republic Steel Corp., Cleveland.

of thickness, regardless of technique, should be included in the term "nondestructive testing". Measurement of strain, too, has received much attention from many other technical groups. It it true that the processes described in the Handbook are nondestructive, but inclusion of methods of measurement raises a question: Are all measurements that are accomplished without damaging the part to be grouped with defect detection under "nondestructive testing"?

In the fields which are in the indisputable area of the term "nondestructive testing", the text is as lucid as possible. It includes many well-prepared charts, diagrams and photographs. Moreover, in many instances, extensive references to other sources of information are included for those readers who might require additional detail. This is particularly true in the section on eddy current testing where European work is cited heavily, almost to the exclusion of American experience. It would appear that U.S. activity in this field has been meager or else has to a considerable extent been disregarded.

Because the nondestructive testing field has become so vast and is growing at such a rate, it was undoubtedly difficult to get certain information into print before it became limited in scope. The committee is to be commended highly for the superb job it has done in this respect, since many of the techniques described were developed and put into service only shortly before the publication date.

In conclusion it can safely be said that the Nondestructive Testing Handbook is a must for the reference shelf of engineers, metallurgists, inspectors and all others who may be involved in this field. It is by far the most complete and detailed survey of nondestructive testing that has ever been published.

A Century-Old Test of Metal

*By HAROLD J. ROAST**

ONE HUNDRED AND TWO years ago, men might have been seen working in the Whitechapel Bell Foundry in London, England, keeping three large furnaces going to melt nearly 20 tons of metal from which a casting was going to be made. The alloy consisted of 23 lb. of tin to 77 lb. of copper. When the casting had been poured and the gates and risers removed it was found that the wastage amounted to only 584 lb., or 1.5%! The records of exact weights are still available, 100 years later.

The metal was run into a mold made of London clay with horsehair and horse manure for binder. The mold was completely dried; to be sure of this, hot air was blown through the mold for 24 hr. There being no pyrometers in those days, the pouring temperature was decided by the Master Founder. (Possibly it was close to 1900° F.) In any event the Master Founder chose correctly.

The casting was a notably large bell and the occasion was looked upon as a social event. A correspondent and an artist from the *Illustrated London News* were present, and that journal printed a wood cut of a drawing showing ladies in their best outdoor finery, escorted by gentlemen in frock coats and silk toppers. Some of the more timid found an observation point in an upper gallery, while the less fearful guests, both male and female, stood on the foundry floor as near as the Master Founder would permit. There was the usual delay as the furnaces came to heat. When the molten metal was tapped it flowed in a bright sparkling red stream, and suitable "Oh's and Ah's" came from the interested spectators. Reaching the pouring basin it only remained for the metal to be suitably deoxidized and degassed.

Now came the critical moment. If the metal were poured too hot or too cold, defects would appear in the casting and the labor and expense of weeks rendered useless. And so the Master

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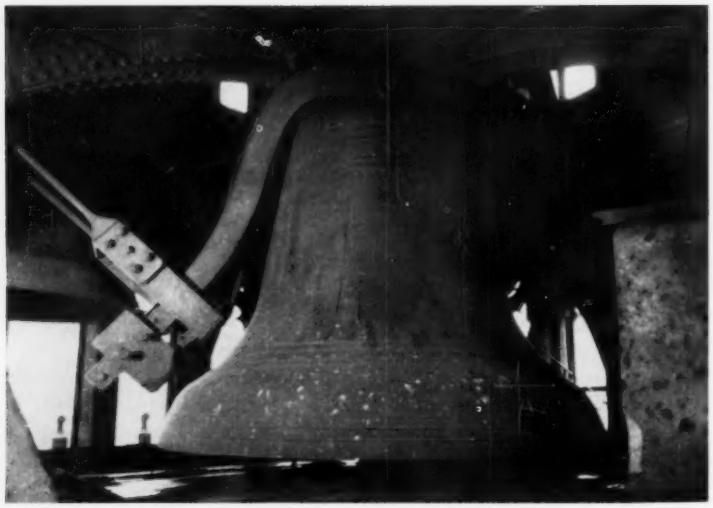


Close-Up of Big Ben in Its Support Atop Westminster Abbey in London. Unfortunately the shadows obscure the handsome design in low relief. (Courtesy Ministry of Works; Crown copyright reserved)

Founder waits, while the guests hold their breath. At last the order to pour is given. As the metal fills the mold, which has been sunk below the floor level, the Master Founder watches the risers which tell when the mold is full. They fill quietly and freely – and, best of all, shrink in the riser heads, showing that the metal had no excess of gas and that the deoxidation had been satisfactory. Furthermore the heavy ingot molds, which had been placed on the cope to weight it down, had been sufficient to resist the upward hydraulic pressure of the rising molten metal.

The bell had been cast. For two long weeks it was allowed to cool. Then came the time for the Master Founder to see the result of his handiwork. The mold material was removed a little at a time, and at last there appeared what was to be known as "Big Ben". Gates and risers were sawed off and the bell hung up so its tone could be tested. Finally it was tuned by machining away a little metal from the inside rim until the desired tone was obtained.

At the end of May 1858, the bell made a triumphal journey from the foundry at Whitechapel to Westminster on a truck drawn by 16 horses, all gaily bedecked.

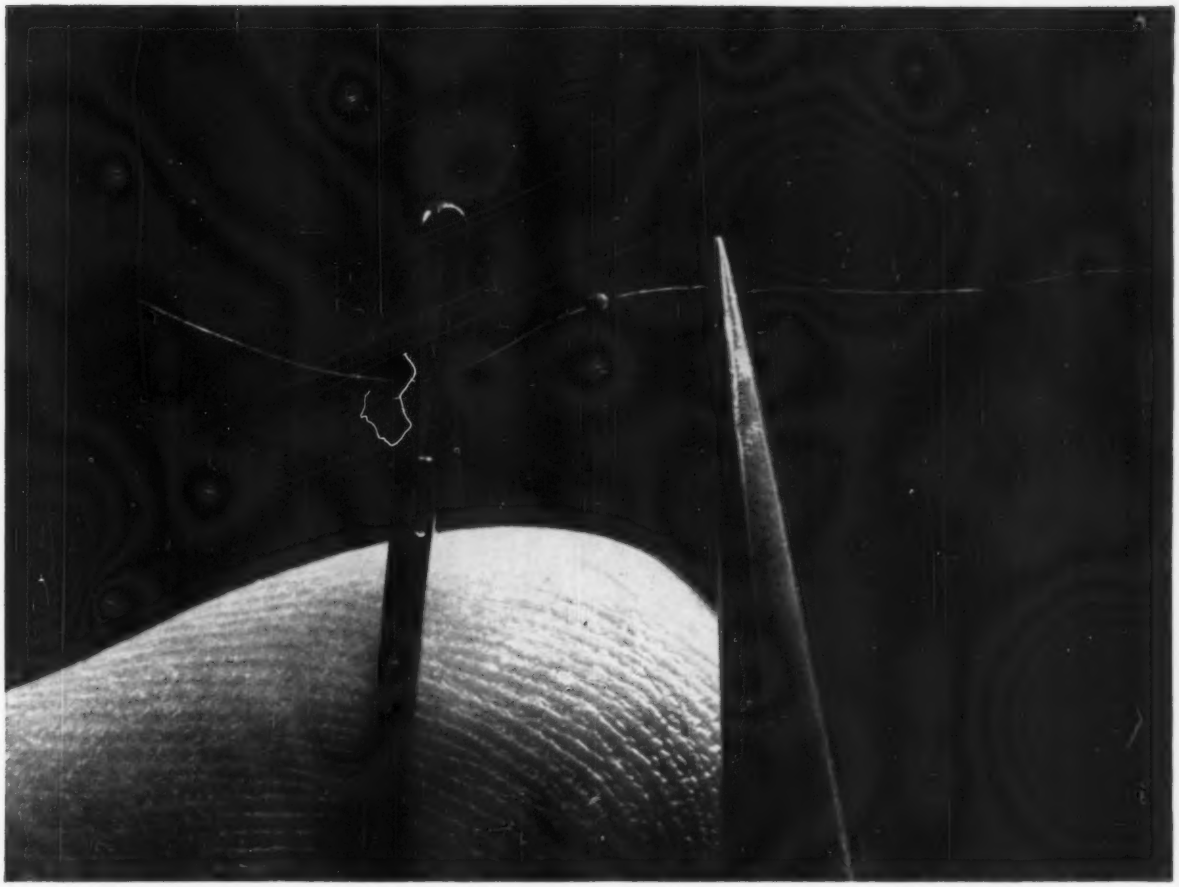
On June 3, 1859, Big Ben struck the hour of eleven in the morning for the first time. Ever since its voice has been heard telling all the world, and especially during the two wars, that London is still a free city of a free people. Only for a brief period during the buzz-bomb raids in 1944 was a recording used, because the tone of the bell revealed enough about weather conditions over London to help the enemy in setting the bomb controls.

On June 3, 1959, at 11 a.m. the Prime Minister of England and Members from both parties assembled in the courtyard of the Houses of Parliament to hear the bell record its centenary.

Big Ben is 9 ft., 10 in. in diameter, 7 ft., 6 in. in total height, and is 8¾ in. thick where the hammer strikes. Its weight is 30,339 lb., as it now hangs. The weight of the clapper is 448 lb. For the first two months a clapper weighing 784 lb. was used and this slightly cracked the rim. The bell was then turned a little away from the first striking spot and the lighter clapper substituted. The crack has never extended and the tone of the bell was not altered. The metal has a shiny appearance where the clapper strikes but no other effect is to be seen. It speaks well for the bronze alloy that the quite tremendous impact of 448 lb. repeated nearly six million times has not harmed the casting.

It is also of interest to note that the specification written by the Astronomer Royal – that "the clock should be accurate to within one second on the first stroke of each hour" – has been met. On the collar around the 13-ft. pendulum are some small copper coins, and the whole mechanism is so delicately adjusted that the removal of one half-penny will cause the huge clock to lose a half-second a day.

One final note: Since 1923 the sound of Big Ben has been broadcast over the whole world, thus becoming an international bell reminding all men of the passage of time (and all metallurgists of the permanence of bronze).



Needle's eye reveals relative size of the thermistor, a tiny bead of Nickel oxide and other materials, used to measure temperatures in and beyond the earth's thin envelope of atmosphere. Made by Gulton Industries, Inc., the thermistor now serves in more than a dozen different missiles and satellites.

"Space thermometer" goes thru needle's eye

Meet the bead thermistor, member of a family of electronic devices now going into everything from midget radios to giant computers and missiles.

This particular thermistor measures temperatures in space — temperatures ranging from 572°F all the way down to 76° below zero Fahrenheit.

You can hardly see the bead with your naked eye. Although it's only *a hundredth of an inch* in diameter, and the lead wires are a mere thousandth of an inch thick, the thermistor is an extremely stable and rugged device, accurate to within a fraction of a degree Fahrenheit.

Made of Nickel oxide and other materials, the thermistor is a space-traveler in many of today's missiles and satellites. It reliably reports on gradients of temperature within the earth's thin atmospheric shield and in outer space. At the same time, it helps record the temperature changes in the missile's skin and its interior.

What is a thermistor? Its name, which comes from THERMal resISTOR, begins to explain. Temperature changes as small as 1/50th of a degree produce a measurable change in the electrical resistance of the pellet. The resulting increase or decrease in circuit current can then be used directly, as a signal, or can be recorded in the form of temperature readings.

Originally developed by Bell Telephone Laboratories for communications equipment, thermistors are now widely used where a tiny, precise, and dependable thermometer is needed: in medical research, in over-load switches to protect electric motors, and in shipment of perishable foodstuffs, for example.

The role of Nickel in the thermistor is only one example of the remarkable versatility of this element.

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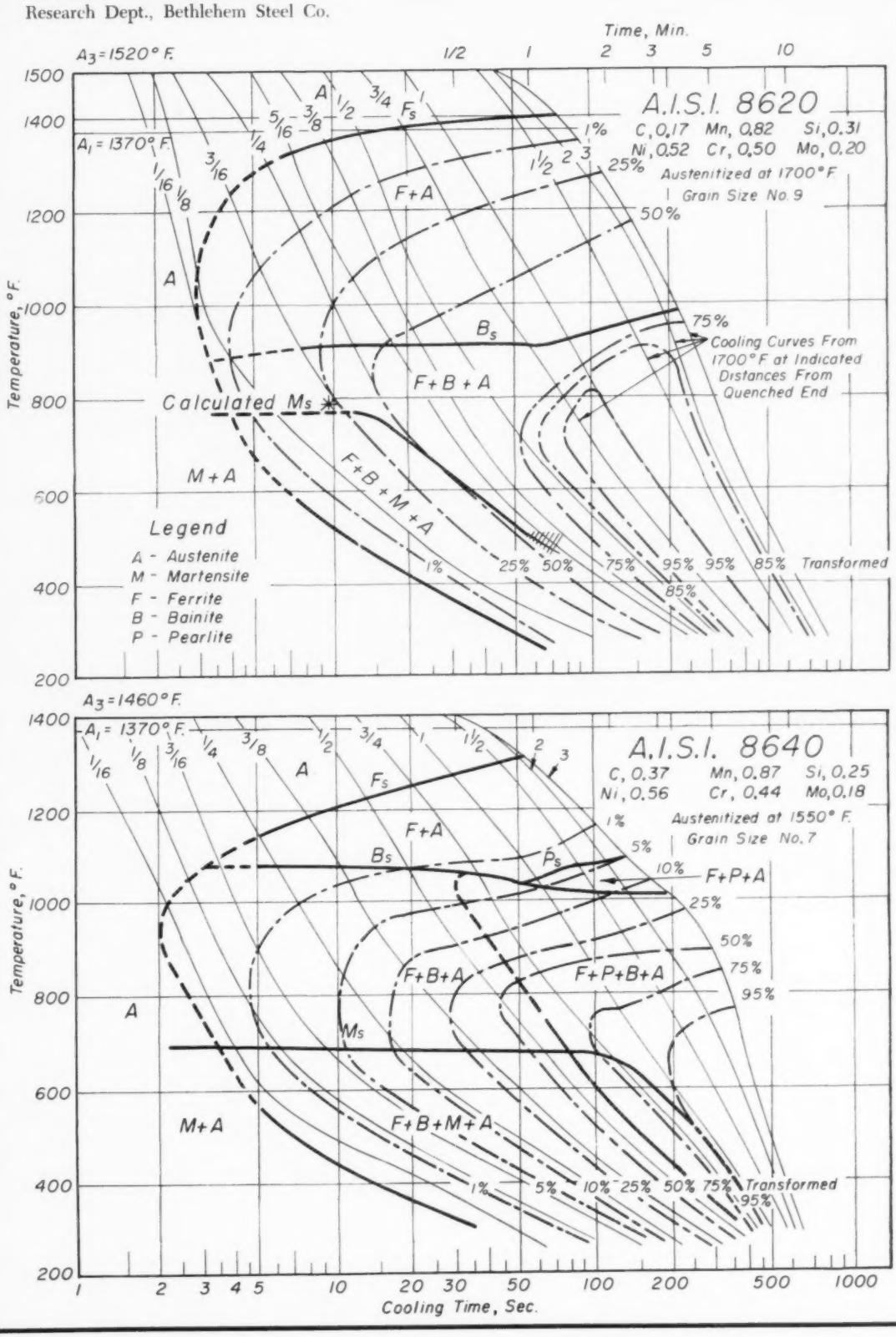
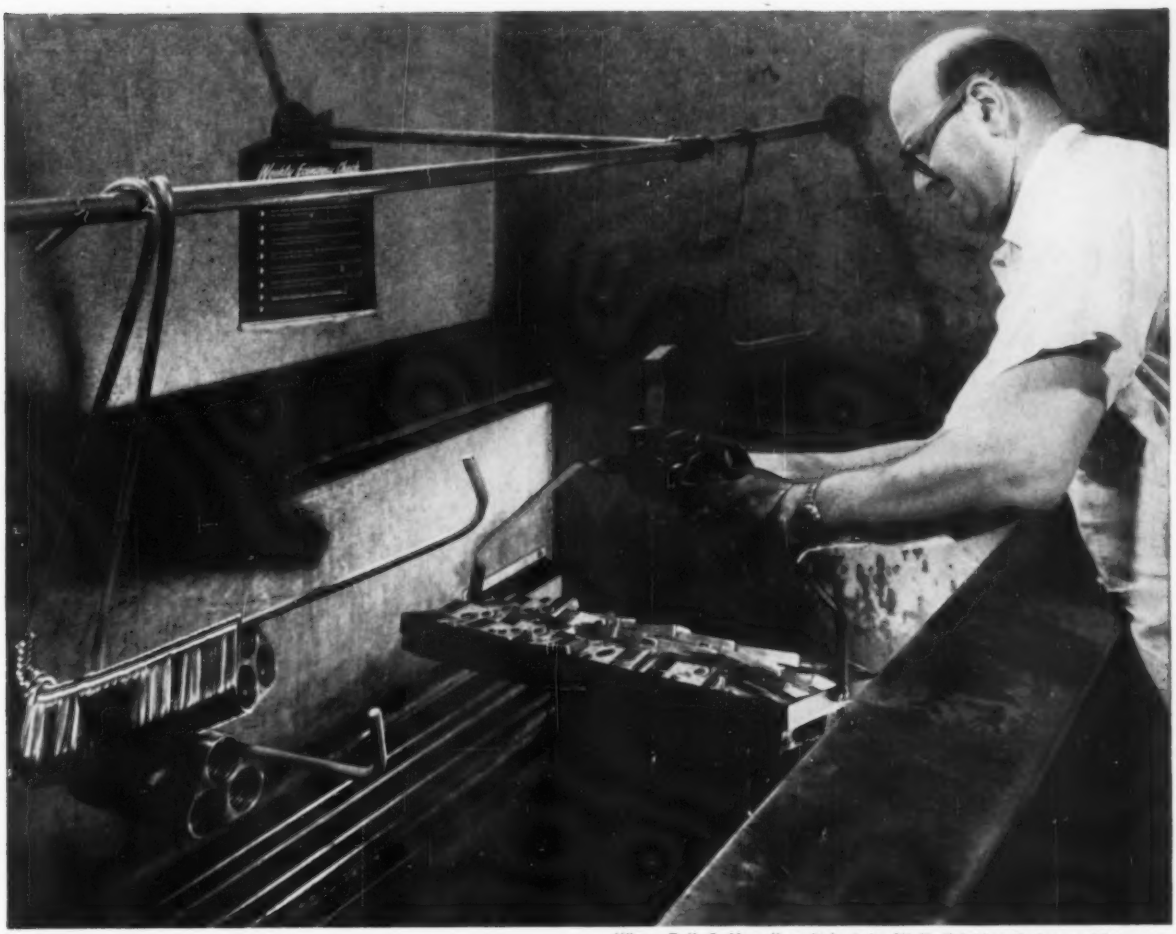
Cooling Transformation Diagrams for A.I.S.I. 8620 and 8640

By R. C. Hess and D. J. Blickwede
Research Dept., Bethlehem Steel Co.





When Bell & Howell switched to Nialk Trichlorethylene with **psp**—permanent staying power, it extended clean-outs to a full three months.

How Bell & Howell degreases 390,000 lbs. of metal parts between bath clean-outs

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The only thing different about the Bell & Howell bath is the Nialk stabilizer. Light, heat, air and acids have no effect on the bath. Even aluminum fines, which can sour trichlor fast, have no effect in the presence of the Nialk stabilizer.

This stabilizer is not extracted by water either; hence all of it is reclaimed during distillation and steam injection. So permanent is the stabilizer that the bath stays fresh and fully protected at all times.

Bell & Howell simply adds more trichlor as drag-out losses lower the bath level; they never have to replenish the stabilizer itself.

FREE BULLETIN • The whole question of stabilizers is so important to anyone concerned with vapor degreasing, we've written a bulletin specifically on the Nialk stabilizer and its advantages. Write for Bulletin 70 if you'd like a copy.

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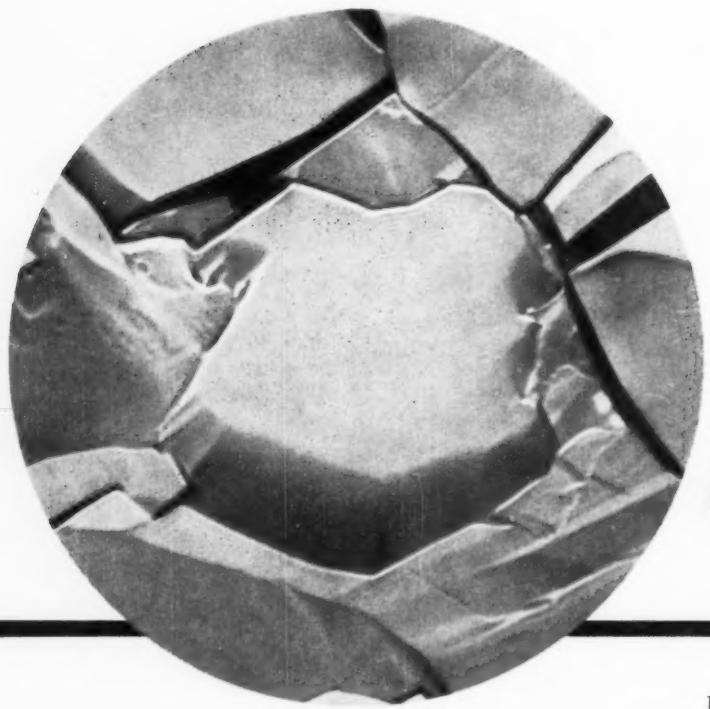

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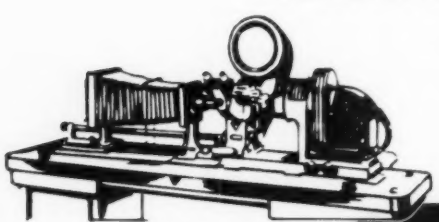

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Circle 2368 on Page 48-B

High-Strength Steel Sheet (300 M)

*By J. C. CHANG, F. J. HERR and J. W. SWEET**

Heat treated to 270,000 psi. tensile strength, it retains 7% elongation at subzero temperatures and 230,000 psi. ultimate at 600° F. Proper welding techniques are necessary to achieve these properties in the joints of missile cases. (Q-general, 3-70; AY, 4-53)

IN LAST MONTH'S *Metal Progress* we compared the properties of modified 4340, studying billets of this high-strength steel made by three methods – basic electric, vacuum induction, and consumable electrode in vacuum. Some extensive work had already convinced us that this analysis, known as 300 M, had several advantages over other low-alloy, high-strength steels for aircraft parts in the 270,000 to 300,000-psi. range, such as high notched-tensile strength, high hardenability, less volume change in heat treatment due to relief of residual stresses, adequate ductility, and superior resistance to hydrogen embrittlement after plating.

The program reported last month was to study the comparative properties of 300 M made by three advanced steelmaking methods. The conclusions were, broadly, that the basic electric steel of aircraft quality is a good material for forged parts heat treated to the 270,000 to 300,000-psi. strength range, and working in the range between −100 to +400° F. The much more expensive vacuum induction steel was not nearly as clean as would be anticipated from statements in the literature, but it was cleaner than vacuum consumable electrode melted steel and basic electric. The vacuum induction steel had excellent transverse properties – in fact its physical tests on the whole were superior to the steel made by the other two methods.

The present paper will present some studies we have made on sheet and thin plate of this same analysis, both *(a)* basic electric and *(b)* induction vacuum melted, together with a few remarks on the strength of welded pressure tanks made from the first mentioned.

Basic Electric Steel

The material tested in this part of the study was taken from a 0.093-in. sheet, 24 in. wide by 72 in. long, sent directly from the Crucible Steel Co. Its chemical analysis is quite similar to the bars so melted and described last month (which were from the same producer): 0.39 C, 0.69 Mn, 0.013 P, 0.011 S, 1.62 Si, 1.88 Ni, 0.81 Cr, 0.38 Mo and 0.08 Al. Under the microscope the grains seemed to be a little more elongated in the 24-in. dimension than in the other. Apparently the sheet had been cross rolled and we took the 24-in. direction to be "longitudinal". As received the tensile properties were:

	TRANSVERSE	LONGITUDINAL
Ultimate strength	110,000 psi.	113,300 psi.
Yield strength	91,700	93,500
Elongation in 2 in.	22.0%	22.0%

Strips cut in either direction could be bent 120° around a pin of 0.187 in. radius (twice the sheet thickness) without breakage. Bend ductility, consequently, was R ÷ T = 2. At 1500

*Messrs. Chang and Herr are research engineers and Mr. Sweet is chief metallurgist for the Aero-Space Division of Boeing Airplane Co. in Seattle, Wash.

magnifications the structure was a uniform dispersion of fine cementite spheroids in a ferrite matrix.

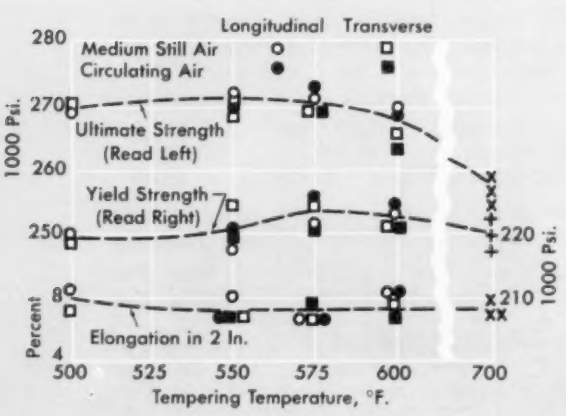
The above sheet was heat treated to 270,000 psi. by normalizing 20 min. at 1700° F., air cooling, and austenitizing 30 min. at 1600° F., and then cooling in still air or in a mild air blast. Samples were then tempered twice, 2 hr. each time, at temperatures ranging from 500 to 600° F., cooling in air after each heating. Results are shown in Fig. 1, which includes samples tempered once at 700° F. in an argon atmosphere and rapidly air cooled. The last-mentioned data were secured from samples heat treated with the welded tanks to be mentioned later. Rockwell hardnesses of these samples were C-53 for the 500° temper and C-51 for the 700° temper.

From these results we concluded that the best combination of strength and ductility resulted from double tempering at 575° F. Longitudinal properties are as follows, and are shown alongside representative longitudinal values for a heat treated bar (see p. 104 in last month's *Metal Progress*):

	0.093-In. Sheet	4 × 5-In. Bar
Ultimate strength	270,000 psi.	290,000
Yield strength	223,000 psi.	244,000
Elongation in 2 in.	7%	9.5%
Reduction of area	—	37.0%
Rockwell hardness	C-52	—
Bend ductility, R÷T	6	—

Transverse properties of the sheet in this condition are about the same as longitudinal

Fig. 1 – Tensile Properties of Basic Electric Sheet as They Vary With Tempering Temperature. See text for heat treating schedule



(268,900; 220,500; and 7.5). Microstructure at 2000 diameters is tempered martensite with no observable second constituent.

Bursting Tests – Since a very important use of high-strength steel sheet is for "booster cases" for missile fuel, eight small pressure tanks were made from this lot of sheet, as received from the steel mill. A rectangular piece of sheet was rolled into a 6.5-in. diameter cylinder and the longitudinal butt joint welded. Draw-formed hemispherical heads were welded on each end, and a threaded fitting for the pressure piping welded into one head. Over-all length was 19 in. Minor mismatch averaging 0.030 in. at all joints (maximum 0.060 in.) was noted due to slight variations in diameters of mating parts, out-of-roundness, and crawling of some of the parts during welding.

The welding techniques for these butt joints may be summarized thus: Tungsten inert gas (TIG) process; 110 amp. direct current, straight polarity; 14 volts; 12 in. per min. Filler material was basic electric melted rod, 0.045 in. diameter, 17-22 AS composition. Shielding gas in the torch was helium (100 cu.ft. per hr.) and 3 cu.ft. per hr. argon for underbead shield. Joint was preheated at 600° F., and this was maintained for 30 min. for post heat.

Heat treatment of these welded tanks was rather complicated. Each was covered outside with "C-R" protective coating*, placed in a retort furnace and purged at least 90 min. with argon. (Argon was maintained on the inside of the tank throughout the entire program up to hydrostatic testing, and as a further precaution against surface oxidation, carburization or decarburization, the furnace carried an endothermic atmosphere balanced so as to be neutral to the 0.40% carbon in the steel.) The tank was heated to 1425° F. for 30 min., the temperature then raised to 1700° F. for 40 min., whereupon the furnace was cooled to 70° F. Next the tank was heated to 1275° F. for 2 hr. and again furnace-cooled to 70° F. The third heating was to 1425° F. for 30 min., then on up to 1600° F. for 40 min., followed by airblast cooling to below 160° F. Finally two of the tanks were tempered at 500° F., three at 600° F. (thought to be optimum for booster cases), and three at 700° F. All eight of the cases broke under hydraulic test in areas associated with the welds. Of the cases drawn at 600° F., one split in the longitudinal weld at 288,000-psi.

*Proprietary coating of Markol Co., of Chicago, to prevent surface changes up to 2100° F.

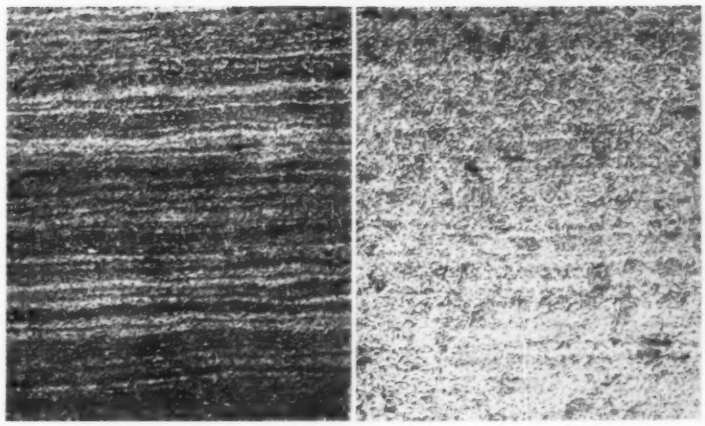


Fig. 2 – Banded Microstructure in 0.150-In. Sheet of 300 M Rolled From Vacuum Melted and Cast Steel, After Heat Treatment (Left, Air Cooled; Right, Oil Quenched). 100 ×; etched in 2% nital

hoop stress and 8000-psi. internal pressure, which developed 106% the unit stress of specimens heat treated alongside the tanks (272,500 psi.). The other two broke at the circumferential weld at 88% and 81% respectively of the strength of the sheet metal.

Twenty-six specimens were cut for microexamination from test pieces welded in the laboratory using techniques similar to those used for the tanks. These specimens showed a number of welding defects such as microcracks, shrinkage, porosity, and inclusions. The results of this examination indicated that the ultimate in welding techniques must be utilized to join this high-strength sheet to realize its superior properties.

Vacuum Melted Steel

A 4 × 8-in. forged bar of induction vacuum melted and cast steel (similar to those studied in the program reported last month) was rolled into three thin plates by Crucible Steel Co., 0.150 in., 0.100 in., and 0.050 in. thick. The other dimensions were 18 to 24 in. wide and 66 to 72 in. long. Chemical analysis was 0.41 C, 0.83 Mn, 0.004 P, 0.007 S, 1.57 Si, 1.93 Ni, 0.84 Cr, 0.06 V, 0.41 Mo, 0.07 Al. (Note the low phosphorus and sulphur.) Grain size was No. 7.

Samples from these sheets were hardened by us and, contrary to the uniform microstructure of the electric steel, noted above, we found a pronounced banding in these sheets. The samples shown in Fig. 2 were each normalized at 1700° F., stress-relieved at 1275° F., and austenitized at 1600° F. Cooling from this last operation was in air to 70° F. for one sample and in oil to 160° F. for the other. Thereupon both samples were double tempered, 2 hr. each at 600° F.

Tensile properties were measured on standard test pieces (reduced section 0.505 in. wide, 2.25 in. between end radii) and results for the 0.150-in. sheet are shown in the following table, which also includes a column giving typical longitudinal properties of the heat treated bars reported in the article last month.

	Air Cooled Sheet	Oil Quenched Sheet	4-In. Bar Oil Quenched
Ultimate strength	258,300	281,900	284,100
Yield strength	241,600	237,700	241,800
Elongation in 2 in.	1.5	6.5	11.0
Reduction of area	–	–	47.3
Hardness	C-54.2	C-53.3	–

This large influence of speed of cooling in the hardening operation on ductility (1.5% elongation if air cooled and 6.5% elongation if oil quenched) applied only to the 0.150-in. sheet. The other two gages (0.05 and 0.10 in.) showed 6.0 to 7.5% elongation in all the tests in our program to develop optimum heat treating cycle. For example, the following tabulation shows that multiple tempering (each one 2 hr. at 600° F.) has small effect on sheets of thinner gages, air cooled. Each figure is the average of three tests.

	Ultimate	Yield	Elongation
0.05-in. sheet			
Single temper	261,900	218,200	6.2
Double	266,100	222,100	6.7
Triple	264,000	221,900	7.0
0.10-in. sheet			
Single temper	262,800	216,800	7.3
Double	263,900	219,000	7.5
Triple	264,100	220,000	7.5

The above samples had been normalized at

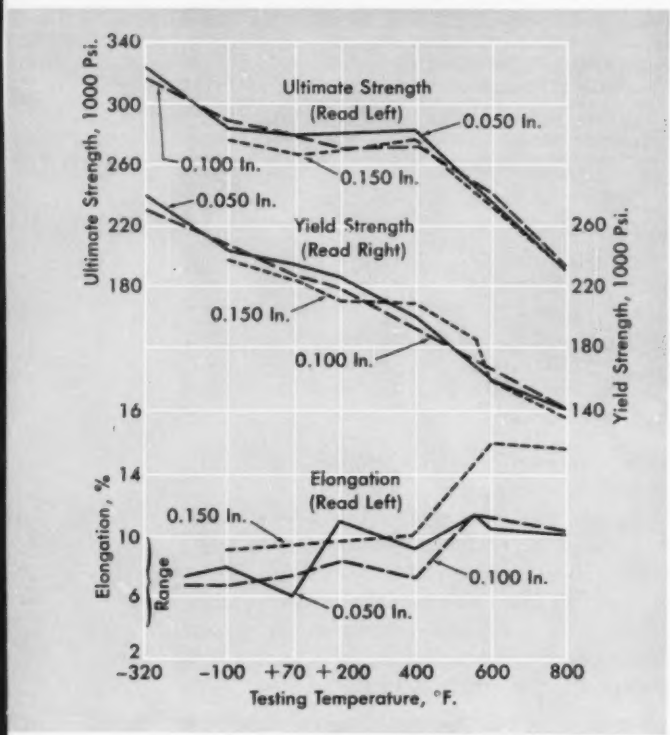
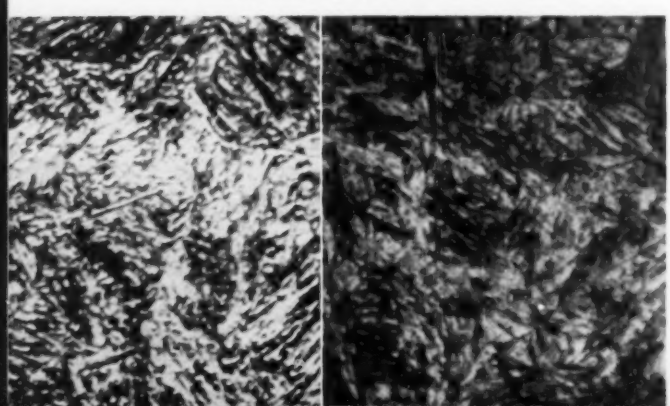


Fig. 3 – Results of Tensile Tests at Low and High Temperatures on 300 M Sheet Heat Treated to 270,000 Psi. Tensile Strength at 70° F.

1700° F., stress-relieved at 1275° F., and austenitized in a salt bath at 1600° F. for 1 hr., then air cooled to room temperature. This, together with double temper, 2 hr. each at 550 to 575° F., was adopted as the best heat treating schedule for the 0.05 and 0.10-in. sheet. After such a schedule the sheets under investigation had about 280,000 psi. ultimate, 230,000 psi. yield and 6 to 7% elongation. The thicker 0.150-in. sheet was treated in the same way, except that it was oil quenched after austenitizing at 1600° F., and double tempered 2 hr. at 600° F. After such a schedule the 0.150-in. sheet had 265,000 psi. ultimate, 220,000 psi. yield and 7 to 11% elongation when tested at room temperature.

Fig. 4 – Structure of Tempered Martensite Existing in 300 M Tensile Specimens After Pulling at −320° F. (Left) and at 600° F. (Right). Villella's etchant, 2000 ×



Since a prime use for such high-strength sheet is in missile cases and fuel tanks, and these might be required to operate at very low temperatures of liquid gas or at very high frictional heats, tensile samples heat treated as noted in the last paragraph were pulled variously at −320 to +800° F. Holding time at temperature before testing was 30 min. Very small differences, if any, appeared in the directional properties, or the scatter of results, except in tests at −320° F. wherein elongations ranged from 4 to 10%. While thickness apparently does not affect the ultimate or yield strength, the elongation figures for the 0.150-in. sheet (which, it will be remembered, was oil quenched) are much more consistent and markedly higher than for the thinner gages.

Microstructure apparently was not affected by the 30 min. at testing temperatures ranging from −320 to 600° F. These extremes are shown in Fig. 4.

Conclusions

From the above tests it would appear that 300 M sheet and thin plate, 0.050 to 0.150 in. thick, can be heat treated to a minimum of 270,000 psi. ultimate and 220,000 yield (at 70° F.) and still retain adequate ductility (6% min. in 2 in.) for well-designed engineering structures. This statement applies both to basic electric aircraft quality steel and to vacuum induction melted and cast steel. The consumable electrode vacuum melted sheet was not available for testing.

It would appear, therefore, that the vacuum melted low-alloy steel 300 M, in sheet form, retains excellent strength and ductility from 400° F. down to −100° F. If really high strength is needed at higher than 400° F., a higher alloy steel should be used, such as H-11, derived from the 5% chromium toolsteel analysis. The ductility of 300 M seems to be erratic at −320° F. Other work shows that the impact strength of 300 M drops significantly below −150° F., but even at −320° F. it remains equivalent to the strong aluminum alloys.

At 600° F. and higher the strength drops off, but ductility is higher than at 70° F.

Fig. 1 – Trend in Prefabricated Metal Buildings Is Toward Structures Which Combine Color With Attractive Design

Color Finishing of Galvanized Steel

Staff Report

Attractive designs in prefinished siding mark a new trend in prefabricated metal buildings. Panels are formed from galvanized strip and then primed with a bond coat which anchors a pigmented vinyl coating to give a long-lasting finish. (G11, L26, T26n; ST, Zn, 8-65)

As far as prefabricated metal buildings are concerned, the era of the Quonset hut and tin shack has died. In their place has come a concept new to the industry but already successful in prefabricated homes. Aesthetic appeal through the use of attractive design and color (Fig. 1) has opened markets which once did not accept the plain-Jane appearance of metal buildings.

Although success of the new concept has hinged on attractive design, much of it stems from the sheet which covers the buildings. This has been the experience of Stran-Steel Corp., a subsidiary of National Steel Corp., Pittsburgh. At its plant in Terre Haute, Ind., the Corporation has in the past few years changed from the once-standard corrugated design to ribbed galvanized siding and has employed a prefinishing process which applies a long-lasting

paint to the sheet before it leaves the plant.

To make the new siding, coils of galvanized strip or aluminum are sent through two lines. One forms the strip to the desired shape, cuts it to size and sprays on a primer or bond coat. The second line covers the primed panels with one of nine pigmented paints. Cost of the painted panels is only about 2¢ per sq.ft. more than those which are unpainted sheet. Its use, therefore, represents a considerable saving since painting in the field after the building is up costs from 10 to 12¢ per sq.ft.

Fifteen-Stand Forming Mill

As a starting material for its color coating process, Stran-Steel uses 10-ton coils of hot dipped galvanized strip (1¼ oz. per sq.ft.) which is processed at the steel mill to remove the rough spangled effect of the coating. (Aluminum strip can also be coated.) The coils are placed on an uncoiler, from which the continuous strip (41½ in. wide) is paid off onto a belt conveyer into the 15-stand forming mill.

Once threaded, the strip is passed through the forming mill which rolls in the profile of the panels thereby reducing its width to 38 in. Wire brushes, bearing on the rolls, prevent buildup of zinc flake. Coming out of the rolls, the strip travels through stiff brushes (Fig. 2) to remove any loose zinc flakes and then under a flying shear which cuts it to proper length. Up until this time the sheet has been traveling about 95 ft. per min. To separate the panels, line speed is increased to about 105 ft. per min.

Bond Coating Applied

Continuing on down the line, the formed panels now pass onto a pin conveyer which carries them through the bond coating booth. Here enough primer is sprayed on from five guns located over the panels so that a ¼-mil (dry) coating remains. This film combines phosphoric acid, chromates and alcohols in a base of vinyl acetal resin. It produces a phosphate coating and a protective film on the sheet and anchors the color coating which is applied later. The treatment not only inhibits corrosion but also prevents flaking.

Coming out of the bond coating booth, the panels travel through a flash tunnel where a fan capable of moving 4000 cu.ft. of air per min. blows most of the evaporating thinner back

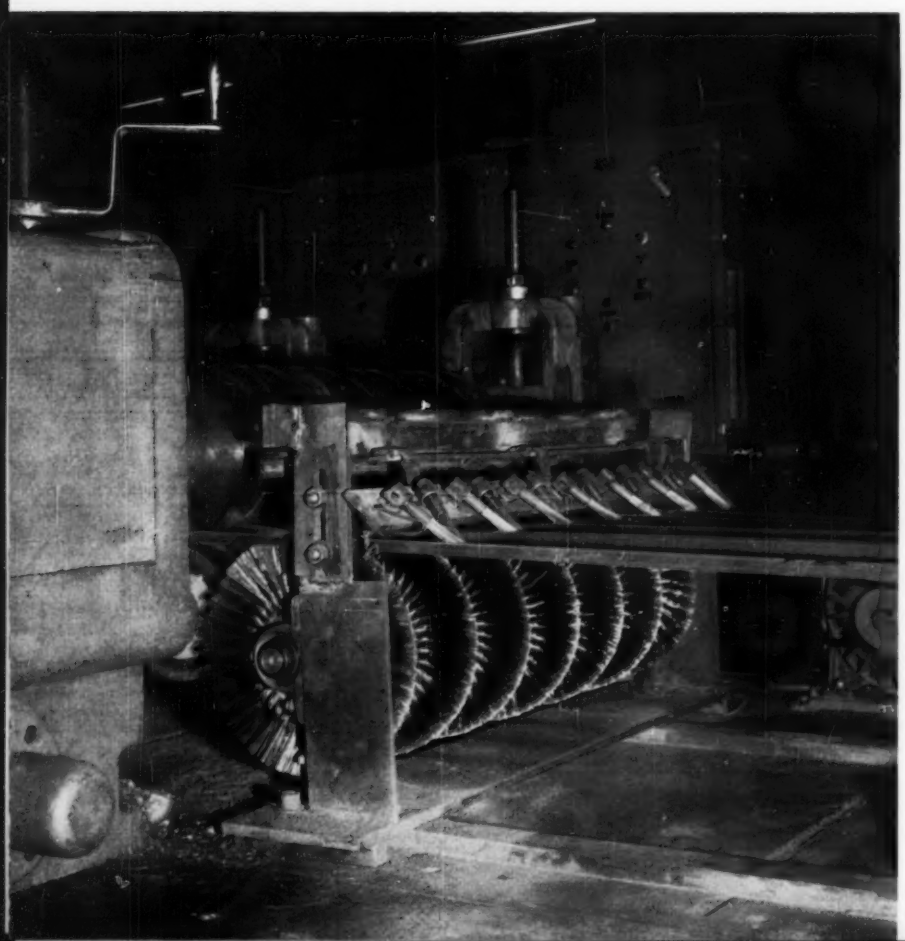


Fig. 2 – Wire Brushes Remove Any Loose Zinc Flakes After the Strip Leaves the Forming Mill

into the paint booth. Then they are dried in a 20-ft. gas-convection oven held at 450° F. and finally passed through a cooling chamber to a run-out conveyer. This marks the end of the first line. Primed panels are transported on dollies either to storage or to the nearby color-coating line.

Uniform Color Coating

First step in the color coating line is to pass the panels under an air blast manifold which blows any possible dirt from the surface. The panels then go into a preheating oven in which infrared heat brings them up to 100 to 125° F. Once preheated the panels are ready for the color coating – a finish based on resin of the vinyl chloride-acetate, copolymer type. They are transferred to a pin-type conveyer which takes them through two spray booths. In the first booth the pigmented paint is sprayed on from eight guns mounted above and in line so that the full width of the panel is covered. Next, the panels are sprayed with paint from eight guns arranged in a circle and rotating rapidly. This setup insures that the panel is covered more uniformly than is possible with spraying from guns mounted in a line. It also insures better coverage on near-vertical surfaces.

Timing of the guns is controlled by a solenoid tripping device which energizes a memory timer. Spraying begins just as a panel passes under the guns. Although the panel travels at 80 ft. per min., each gun sprays only when a panel is below it. About 5 mils of paint is sprayed on; this dries to a thickness of 1¼ mils.

Much of the success of the color coating line stems from the excellent paint storage and distribution system (Fig. 3). Paint is circulated continuously from two 120-gal. tanks for each of the nine colors at 80 psi. through 7700 ft. of piping. It travels from the storage and distribution center to the coating line through an underground tunnel which is heated to keep the paint at proper viscosity. In the paint booth, only 3 min. is required to change from one color to another.

Four-Zone Oven Cures Paint

As the panel leaves the spray booths it goes through a flash tunnel. Next step is to dry the paint in a four-zone drying and curing oven.

In the first zone, temperature is maintained at 275° F. by a 600,000-Btu. per hr., gas-fired burner and three banks of infrared tubes. Since the paint is still wet, it can take this high heat for a short time without damage. The hot oven temperature dries the paint surface, whereas the infrared heats the metal surface, thus drying the paint from the inside.

Fig. 3 – Storage and Distribution System Supplies Paint to Color Coating Line Through 7700 Ft. of Piping. Paint is circulated continuously through the distribution pipes

From this zone the panel moves into another which is held at 175° F. by a 300,000-Btu. burner and two banks of infrared tubes. Less heat is used here to prevent blistering since some of the thick paint layer is still liquid.

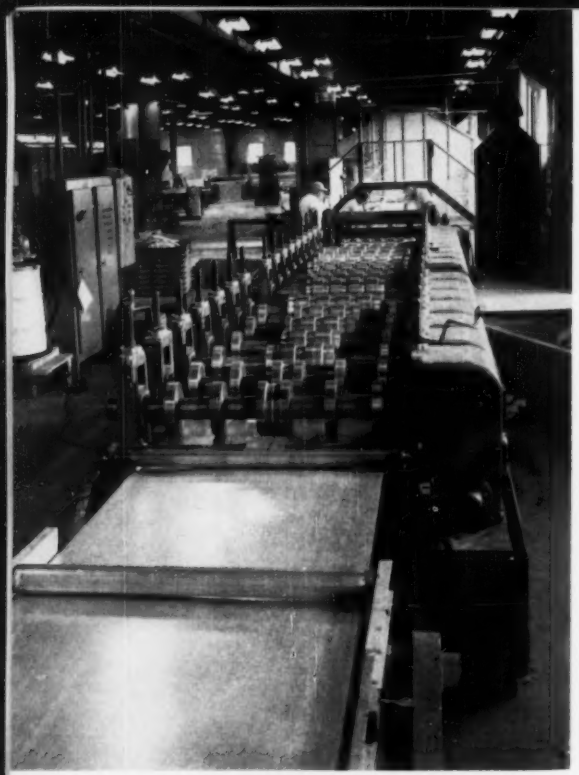
In the next zone the furnace air is raised to 200° F. Finally, in the last zone the temperature is raised to 300° F. By the time the panels emerge from the oven, they are at 200 to 210° F.

Cooling, necessary to permit packaging at the end of the line, is hastened by a water quench from spray guns and a 50-ft. cooling area, containing six large, low-rpm. fans, each capable of moving 1200 cu.ft. of air per min.

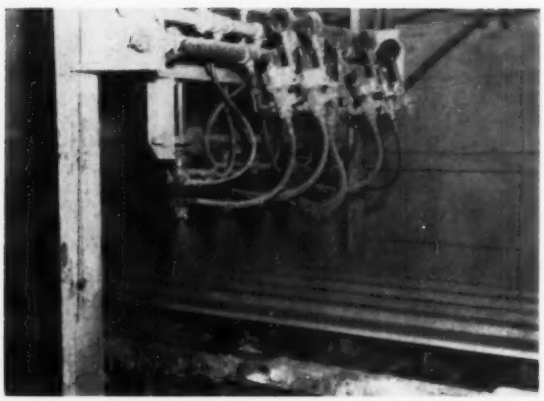
Panels then continue to a run-off conveyer from which they are unloaded to packaging dollies. Each bundle must be carefully wrapped and protected from rough handling in the field. The sequence of production for color coating is given on the following pages.

More on Color Coating

Finishing Lines Produce Color-Coated Panels

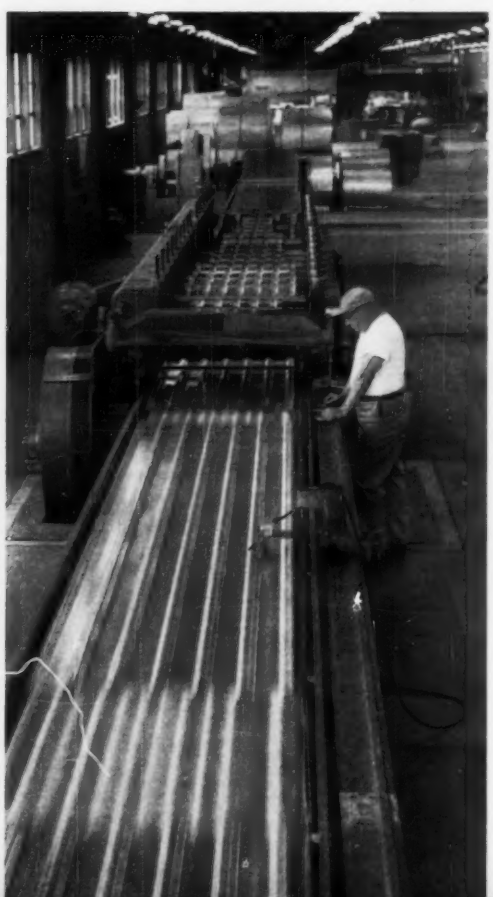


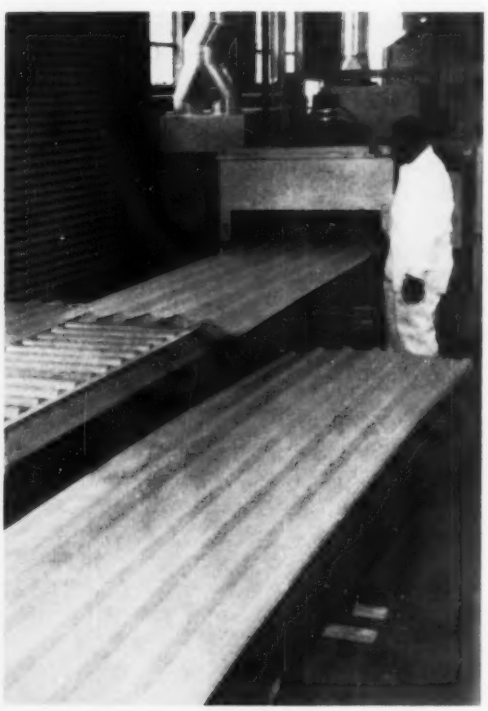
1 *. . . Galvanized strip enters 15-stand forming mill*



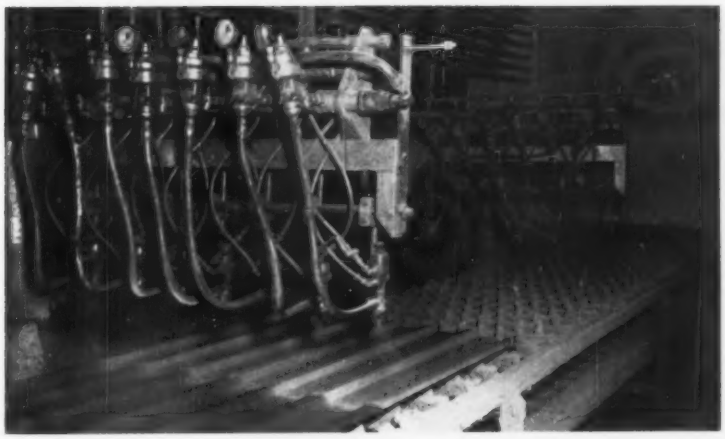
3 *. . . Panels moving at 105 ft. per min. get primer spray*

2 *. . . Formed steel passes under flying shear, is cut to proper length and accelerated for separation*



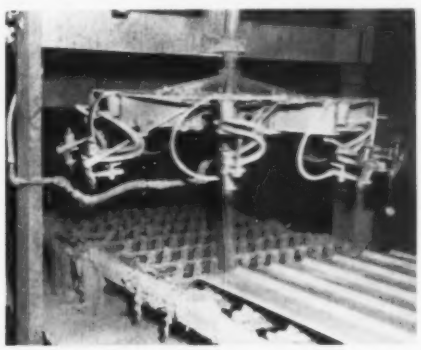


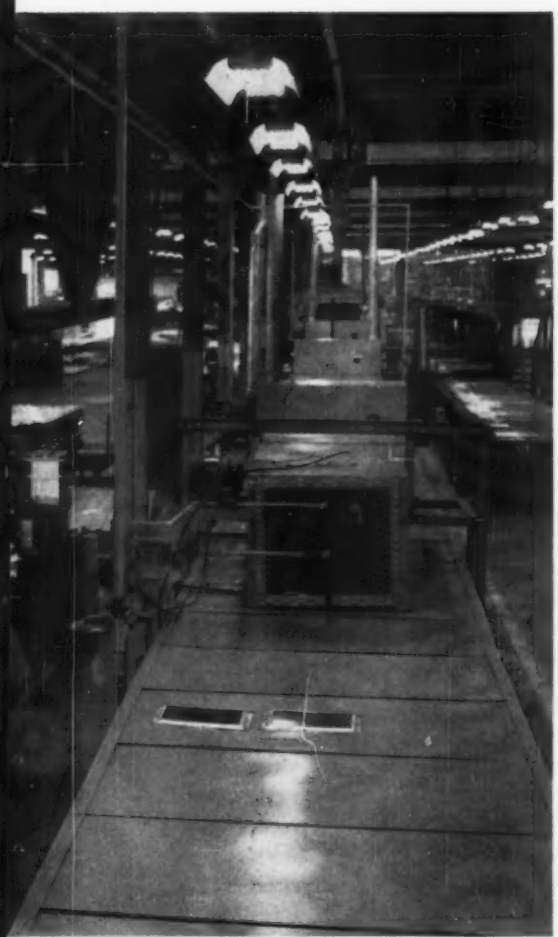
4 *. . . Dried sections roll out of drying oven for transfer to nearby color coating line or storage*



5 *. . . Primed panel, preheated in first stage of color line, receives color coating*

6 *. . . Rotary sprayer finishes color application, assures uniform coating*





7 *. . . Drying oven heated by gas-fired burners and infrared tubes cures paint in four stages*

8 *. . . Water quench and high-volume fans cool panels for immediate packaging*

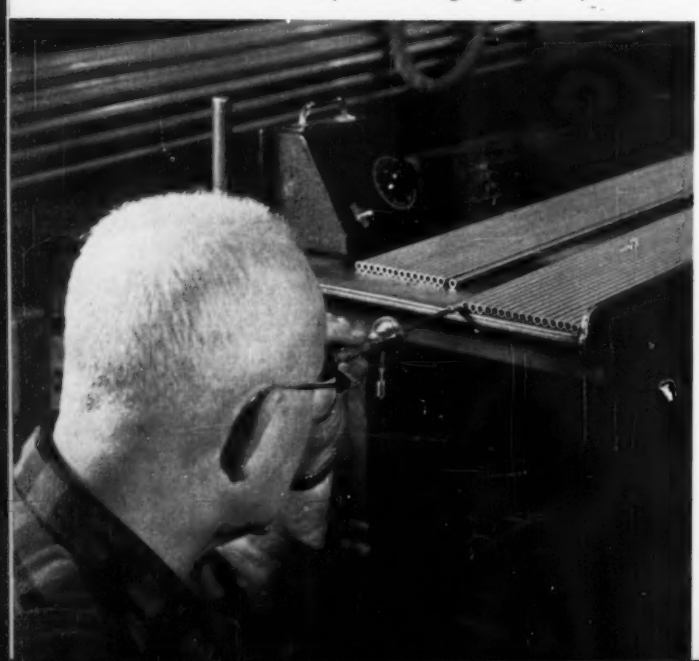
Nondestructive Testing of Small Tubing

By J. R. GRIEVE
*and A. M. BOUNDS**

This article compares eight nondestructive testing methods – visual, boroscopic, eddy current, dye penetrant, magnetic particle, ultrasonic, radiographic, and hydrostatic – which can be employed to locate defects in tubing nondestructively. Though eddy current testing is considered to be the most versatile method in present use, no one test can give a complete answer by itself. Only the proper combination of tests will tell the whole story. (S13; 4-60)

IN THE MANUFACTURE of such critical items as atomic reactors and missiles, small tubing plays a vital though little-noticed role. Naturally, hydraulic tubing for applications as critical as these must consistently be of the highest quality. As a consequence, producers of small tubing find that nondestructive testing is essential. Furthermore, several types of tests must be available, no one test being versatile enough to supply all of the required information. In this article, these tests, which as Table I shows include visual, boroscopic, eddy current, dye penetrant, magnetic particle, ultrasonic, radiographic and hydrostatic tests, are compared in terms of their ability to detect "defects" – that is, imperfections which are serious enough to cause rejection. (However, all tests, within their limits, will also discover imperfections which are not cause for rejection.)

Fig. 1 – Examining Small Tubing With a Boroscope. Used for inspecting inside diameters, this test is time-consuming and requires a high degree of skill



Visual Tests

Examination of tubing, either with the naked eye or, more generally, under magnification, is common practice in tubing mills. Inspectors employ a magnifying glass to inspect the outside diameter, and a boroscope (see Fig. 1) for the inside diameter. Both tests require a considerable amount of inspection time, and both are limited to finding surface defects. Their effectiveness depends, to a large degree, on the skill and conscientiousness of the inspectors. Boroscopic examinations, in which the tubes are rotated while the instruments traverse

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them, are particularly slow and tedious, and require a high degree of operator skill.

Another limitation in boroscope testing is the size of the I.D. which can be inspected (0.140 in., minimum) and the distance that the instrument may be inserted (about 3 ft. maximum for small tubing – about 3/16 in. I.D. – and about 20 ft. maximum for larger tubing). In practice, boroscopes are often used along with eddy current tests to determine whether the area which has caused an indication is really defective.

Eddy Current Testing

At present, eddy current testing – also known as electromagnetic inspection – offers the best combination of advantages for examining small tubing. Simply described, the equipment consists of two electrically balanced coils adjacent to each other which induce eddy currents in the tubing as it passes horizontally through them. (The electronic principle is the same as that used in induction heating.) If any flaw passes through the first coil, it changes the resistance to the induced current in that coil, thereby throwing the coils out of balance with respect to each other. This imbalance is amplified; it can then be indicated audibly by a loudspeaker, visibly by neon light, or recorded. The system can also be set up to detect variations in chemical composition (such as the difference between Type 316 stainless steel and Inconel) and gross variations in dimensions. Figure 2 illustrates an eddy current testing operation.

For small tubing – which encompasses a variety of sizes, wall thicknesses, materials, tempers and surface conditions – a single-channel, single-frequency tester is inadequate. Equipment with two control units – each of which has two flaw detection channels, one property-variation circuit and one frequency-selection unit – has been found most effective. Twenty-one different frequencies from 1.8 to 700 kc. can be selected for test purposes. With this equipment we can detect a number of variations from normal and ascertain their position, character and relative size; detect changes in chemistry and tubing size; and inspect simultaneously for surface and subsurface defects.

Notch Standards Essential

One problem in connection with the use of any eddy current testing equipment is to determine whether the defects it picks out make the tubing rejectable or not. So far, the best

Fig. 2 – Eddy Current Tester in Operation. If the tube section passing through the coil contains a flaw, it is signaled electronically. The signal can be set to flash a light, sound an alarm, or record an impression in ink

answer has been the use of standard reference tubes fabricated with notches of predetermined size on the outside surface in a longitudinal direction near the center of the tube. The inspection is adjusted in such a manner that it gives a clear indication of the presence of any defect in the tubing which is as large or larger than the notched standard. If the tubing has a defect which gives a signal equal to or better than that for the notched standard, the tubing is classified as rejectable. We have found the most practicable standard to be a notch 0.004 in. deep on tube walls 0.040 in. thick and greater, and a notch cut to 10% of wall thickness on walls less than 0.040 in. thick. Tolerance on depth of the reference notch is held to plus 0.000 in., minus 0.0005 in.

The advantages of eddy current testing are many. Although the cost of the original equipment is comparatively high, it can be operated with average skill, and it is very fast. Ordinarily, tubing is tested at about 250 ft. per min., but the speed may be increased to 1000 fpm. if vibration can be kept within limits.

Despite its high speed (which permits mass production inspection), the test is very sensi-

Table I – Nondestructive Tests for Small Tubing

Type of Test	Relative Cost of Equipment and Materials	Skill Required	Speed of Testing	Subject to Inspector's Judgment	Defects Revealed		
					Outside Diameter	Inside Diameter	Subsurface
Visual							
Magnifying glass	Low	Average	Average	Yes	Yes	No	No
Boroscope	Average	High	Slow	Yes	No	Yes	No
Eddy current	High	Average	Very fast, used for mass production inspection	No, if alarm circuit is used	Yes	Yes	Yes
Dye penetrant							
Visible	Low	Average	Slow	Yes	Yes	No	No
Fluorescent	Average	Average	Slow	Yes	Yes	No	No
Magnetic particle	Average	Average	Slow	Yes	Yes	No	Yes (Max. ⅜ in. below surface)
Ultrasonic	High	High	Average	No, if alarm circuit is used	Yes	Yes	Yes
Radiographic	High	Great skill required	Very slow	Yes	Yes	Yes	Yes
Hydrostatic	High	Low	Average	No	No	No	No

*Difficult to see pips on oscilloscope for tubing with less than 0.049 in. wall thickness.

tive. It will detect numerous types of imperfections (including pits, gouges, cracks, inclusions, weld defects, carburization, surface oxide, porosity, roughness, corrosion, laps and embedded particles) which may be present in tubing. Particularly useful in revealing tight discontinuities, it will detect such imperfections on the O.D. or I.D. and will do so on tubing from the smallest size up to tubing with a 3-in. O.D. and with walls ½ in. thick. Eddy current testing has also been used to detect changes in O.D., I.D. and wall dimensions (though it cannot tell which dimension has changed), and in chemical composition of the material.

To set eddy current testing in its proper perspective, however, it is well to point out its limitations (most of which are found in other nondestructive tests also). First and foremost, it will not measure the depth of defect (the principal factor in detecting rejectable tubing), nor can it clearly differentiate between the type of flaws. Because the method is highly sensitive, it responds to a large number of variables such as grain size, stress concentrations, minor inclusions, changes in magnetic properties, small changes in dimensions – none of which is usually considered a cause for concern. (An added complication is that a given variable may be perfectly acceptable in one application but cause for rejection in another.) Eddy currents will not tell whether the defect is on the O.D. or I.D. (except on heavy-wall tubing or by means of dual-frequency equipment), or in the wall of the tubing. And finally, natural defects do not necessarily correlate with artificially produced defects of rejectable level.

Despite these minor drawbacks, Superior has been using this method since 1955 for testing tubes to be used in fuel elements and heat exchangers for nuclear use, as well as tubing for other critical applications. (The customer

Table I – Continued

		Limitations		
Changes in Analysis	Changes in Dimension	Metals	Defect Depth	Tubing Size
No	No	None	None	None
No	No	None	None	Length of I.D. inspection depends on size of tubing
Yes	Yes	None	None	No lower limit. Upper limit: about 3 in. O.D.; 1 in. on wall thickness
No	No	Not good for porous metals	None	None
No	No	Not good for porous metals	None	None
No	No	Magnetic materials only	None	Not practical on very small tubing
No	Sometimes, under certain circumstances	None	None	Minimum limit on O.D.: ½ in.*
No	Indirectly	None	None	None
No	No	None	Only penetrating cracks and defects which penetrate when pressure is applied	None

can also specify the test if desired.) We have found it to be a fast, sensitive method for testing tubing in our size range. In spite of its limitations, it is the one best method for production inspection of tubing as far as we are concerned.

As to improvements, what is most needed, for the present, is agreement between vendor and customer on acceptability standards. In the future, we will also need eddy current machines which will retain their sensitivity without background noise and which will distinguish between a wide, shallow defect and a narrow, deep one. (Present equipment is sensitive only to the relative *volume* of a defect.)

Dye Penetrant Tests

If nondestructive tests were to be rated by their all-around usefulness, dye penetrant testing would place right after eddy current inspection. Actually, it is quite different from eddy current testing since the human eye rather than a machine is used to detect the flaw. In fact, dye penetrant testing may be considered an extension of the human eye.

There are two kinds of dye penetrant tests, visible and fluorescent. The first (shown by Fig. 3) uses only a red dye while the other, the fluorescent test, uses fluorescent dye and requires ultraviolet light.

In the visible test, the red dye is dissolved in a light oil of such viscosity and surface wetting nature that it is rapidly sucked into tight cracks and crevices. After the excess dye is wiped off with a solvent, the tubing is coated with a white colloidal suspension known as a developer. The red dye oozes from the flaw, and bleeds through the white developer; this makes the defect readily visible.

If more sensitivity is desired, the fluorescent test is used. Though the application is somewhat more complicated than with the visible

Fig. 3 – For Dye Penetrant Testing, the Three Tubes in the Foreground Have Been Coated With a Red Dye Which Is Subsequently Wiped Off. The tubes are then coated with a white developer (see tubes in background), and any dye remaining in cracks or fissures bleeds through

method, the action is similar. The fluorescent dye seeping from the flaw bleeds through the developer. When the tube is examined in a dark booth under black (ultraviolet) light, the defect glows. Though this test gives greater contrast than the visible dye penetrant test, the latter is sufficient for most requirements.

Because of their extremely high sensitivity, both tests will often pick up defects missed by eddy current or ultrasonic inspection. Sometimes this is a disadvantage since they will show imperfections which may not necessarily be classed as defects.

As for equipment, only the simplest is required for the visible test (a rack and some rags), and equipment for the fluorescent test is not costly compared to that required for some of the other nondestructive tests. There is no limit as to the type of metal the method will test (except that porous metals will give false indications). Furthermore, only average skill is required in operation.

The principal limitation on dye penetrant tests is that they are slow. Consequently, they are expensive, unless they are part of an automatic production unit. Moreover, dye penetrants can be used only to detect flaws on the O.D. surface of the tube because the dye cannot penetrate into defects below the surface. Finally, on small tubing, dyes show only that a flaw is present, not how deep it is.

As stated before, the dye penetrant test is a good companion to the eddy current test. Both should be used whenever permitted by inspection cost allowance.

Magnetic Particle Testing

When a magnetic field is induced around a piece of ferromagnetic metal tubing, a north magnetic pole is formed at one end and a south pole at the other. At the same time, any cracks in the tubing, whether on the surface or beneath it, also form magnetic poles. Thus, when the magnetized tubing is coated with fine particles of magnetic iron, the particles cling to the defect like tacks to a simple magnet. Appearing as black lines, the size of the particle build-up gives an indication of the severity of the defect. Here again, as in the eddy current test, the method is volume sensitive, not depth sensitive.

Sometimes, when the contrast is not sufficient, the test piece is dipped in a fluorescent solution, and then washed clean. Since particles of the fluorescent iron powder remain in the tiny cracks or flaws, they show up when the tubing is examined under ultraviolet light.

The magnetic particle test, which is not as sensitive as the dye penetrant tests, is used on large metal surfaces more often than on small tubing. Also, it is limited to metals which can be magnetized, and test pieces must often be demagnetized after the test is made. As with dye penetrant testing, the method is comparatively slow and requires some skill. However, it is useful in detecting flaws on or just beneath the surface, and it does give some indication of the size of the defect.

Ultrasonic Testing

In ultrasonic testing, sound waves with extremely high frequency are directed through the tubing by a quartz *(Continued on p. 126)*

Bimetallic Heat Exchanger Tubes Solve Dual Corrosion Problem

*By W. G. ASHBAUGH and S. E. DOUGHTY**

Failure of heat exchanger tubes was stopped by switching to bimetallic tubing. Copper on the outside prevents pitting and stress-corrosion cracking caused by brackish cooling water; stainless steel on the inside withstands corrosive action of chemicals being processed. (R1d, R2j, W13b, 17-57; Cu, SS, 4-60)

CHEMICAL PROCESSING PLANTS in coastal areas are frequently faced with the problem of providing an effective barrier between two dissimilar corrodents in heat exchangers. Because they are close to the sea, the plants commonly use salt water or brackish river water as a cooling medium. The process liquid or gas is totally different and corrosive in nature. Yet both the water and the product must be handled simultaneously in the same exchanger.

Corrosion on One Side

As a rule, stainless steel tubes successfully withstand the corrosion attack on the process side. Carbon steel tubes, in fact, serve the purpose if the chemical reagent is mild enough. But neither metal will hold up under long exposure to the chloride ions in brackish cooling water which frequently cause stress-corrosion cracking and pitting in heat exchanger tubes (Fig. 1).

Severity of attack depends on the concentration of the corrosive medium and the service conditions encountered in each application. Thus, it is frequently found that a single grade of stainless or any other material will not successfully resist attack from both the process and cooling sides of the tubes. The answer to this problem lies in the use of bimetallic tubing — stainless for the process side, and a copper-base alloy for the cooling water side.

Applications in Chemical Plant

This type of tubing, made by drawing copper or brass over welded stainless tube, has been used in three instances by Union Carbide Chemicals Co. to solve the problem of dual corrosion. At the company's Texas City plant, for example, seven vertical condensers handle hot corrosive gases on the tube side and brackish river water on the shell side. All of the product passes through these seven exchangers which condense hot process gases and vaporized liquid from the reactor. Once condensed it is passed on for distillation and refining.

Each condenser contains 475 tubes (¾ in. O.D. by 12 ft.) which must be austenitic stainless to prevent corrosion and contamination of the product. Unfortunately, in every austenitic stainless grade put into service, stress-corrosion cracking (Fig. 2) and pitting show up on the cooling water side. No attack occurs on the inner wall of the tube; all of the difficulty stems from exposure of the tubing to the river water which contains 200 to 500 ppm. of chlorides. Corrosion is particularly severe at the inlet end of the condenser where tubes are heated to more than 300° F. When the water, which

*Mr. Ashbaugh is corrosion engineer, Union Carbide Chemicals Co., Texas City, Tex., and Mr. Doughty is manager, technical services, Alloy Tube Div., Carpenter Steel Co., Union, N.J.

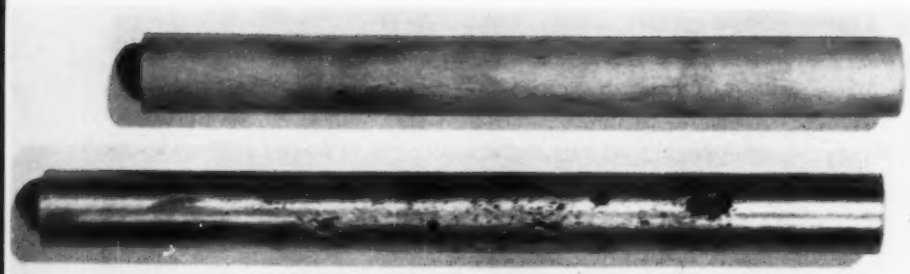


Fig. 1 – Comparison of Corrosive Attack on Two Stainless Alloys. Type 316 stainless tube (top) failed by stress-corrosion cracking. Type 329 tube (bottom) failed by pitting. Both failures were brought on by high chloride-ion content in cooling water surrounding the tubes

enters at about 100° F., hits the hot tubes, salts precipitate which collect on the outer surface. The salt scale builds up and acts as insulation, thus making the tube surface still hotter and accelerating corrosion. As a result, widespread pitting and stress-corrosion cracking occur.

In the original design, Type 347 stainless steel tubes were used, but these failed after about 1½ years of service because of chloride stress cracking. Then Type 316 stainless tubes were tried. They proved to have better corrosion resistance than necessary for the process side, but were still inadequate for the water on the shell side. There was no significant improvement in service life.

The company then tried tubes of a special stainless grade (0.20% max. C, 23 to 28% Cr, 2.50 to 5% Ni, 1 to 2% Mo.) These tubes lasted about 22 months. A second bundle of the same type of tubing was installed after special heat treatment to normalize the grain structure. These tubes lasted a little longer than two years before they also failed. Although they resisted stress-corrosion cracking, they did not resist the pitting action of the chloride-bearing water.

To solve the problem a new condenser was built using bimetallic tubes of Type 304 welded stainless tubing (18 gage) mechanically bonded to 0.035-in. deoxidized copper (Fig. 3). Type 304 ferrules were used on the ends of the tubes to present an all-stainless surface to the process. The shell was of Type 304 stainless, and the baffles of brass. As with the previous exchangers, this unit was designed with a floating top head and a fixed bottom head.

Fig. 2 – Typical Stress-Corrosion Crack Found in Austenitic Grades of Stainless Steel After Service in Water of High Chloride Content

Since their installation, the bimetallic tubes have been in uninterrupted service for almost five years, well over twice as long as the most effective bare tubes. They have caused no trouble and required no maintenance other than a periodic flushing of the shell side with cleaning acid. It is probable that the bimetallic tubes will last at least eight to ten years.

Now eliminated are all the costs formerly involved when one of these units was down for repairs. Replacement of the tubes alone cost between $10,000 and $15,000. Cost of rebuilding the bundle ran between $800 and $1000. When one condenser was out of service, it meant loss of one-seventh of the unit's production during the time required for maintenance or replacement. The production loss during the brief time needed to install a standby replacement bundle amounted to $2000 to $3000 on each occasion.

The plant now saves from $12,800 to $19,000 every two years. Total saving, prorated over the life expectancy of the bimetallic tubes, amounts to at least $51,200 for eight years of trouble-free service, or at most $95,000 for ten years of trouble-free service.

Bimetallic Tubes Prevent Leaks

Union Carbide's plant at Seadrift, Tex. is another place where bimetallic tubing has proved advantageous. Here, difficulty arose with a vertical cooler handling hot corrosive gases inside the tubes and brackish cooling water on the outside. The unit is a single-pass, outside-packed floating head exchanger with removable tube bundle. Original design called for 737

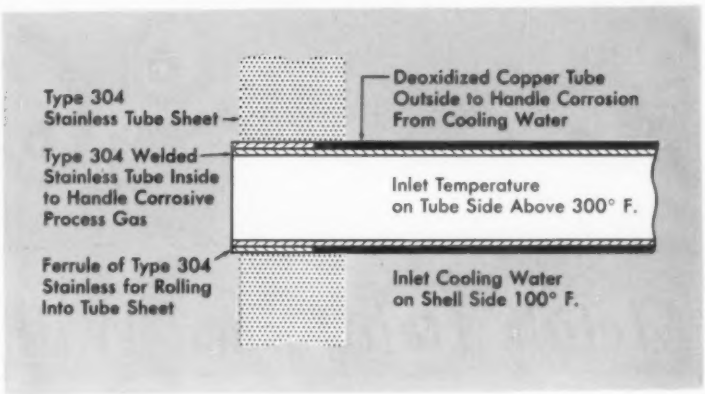


Fig. 3 – Plagued by Failures in Heat Exchanger Tubing, Engineers at Union Carbide Chemicals Co., Texas City, Tex., Designed a New Condenser Based on Bimetallic Tubing. Original tubes of Type 347 stainless were replaced by copper-over-Type 304 tubing joined to tube sheet as shown here

Type 304 tubes each ¾ in. in O.D. and 18 ft. long. The tube sheet and baffles were also of Type 304 stainless.

Cooling water temperature in the winter is about 70° F., and in the summer, about 90° F. The cooler is designed for a normal outlet gas temperature of 95° F. Pressures and velocities are relatively low.

Once again, the stainless tubes withstood the corrosive elements in the process gas, but the material was not compatible with the chloride ions in the river water. This incompatibility became particularly acute during the dry seasons when there was a build-up in the chloride content of the cooling water drawn from the Guadalupe River. Mild pitting attack was widespread on the tubes. Stress-corrosion cracking was particularly severe near the top tube sheet because of the vapor phase created in this area. Leakage problems plagued the plant for about 4½ years. Each time a leak occurred, it was necessary to plug off the defective tube.

A completely new tube bundle was then built and installed in place of the old one. The new bundle consisted of bimetallic tubes (20-gage copper lightly drawn on the outside of 18-gage stainless). This replacement bundle has been in continuous operation for over 1½ years without showing any sign of trouble.

Table I – Cost Comparison of Plain and Bimetallic Tubing

Tubing	Cost Per 100 Ft.*
Type 304†	$90.65
Type 316†	113.51
Admiralty brass over Type 304‡	111.28
Deoxidized copper over Type 304‡	111.10
Deoxidized copper over Type 316‡	128.74

*In 5000-ft. lots.

†¾-in. O.D., 16-gage.

‡¾-in. O.D., 20-gage copper or copper-base alloy over 18-gage stainless steel.

The Seadrift plant encountered somewhat the same problem in another unit—a vertical condenser located on top of a fractionating column. The original tubes were Type 304 stainless to resist the hot corrosive vapors and gases containing hydrocarbons that are carried on the process side. The chloride ions in the brackish cooling water, however, attacked the outer walls and caused repeated leaks that had to be plugged periodically for nearly 4½ years.

This unit was retubed with bimetallic tubes of 19-gage admiralty on 16-gage Type 304 stainless steel. There are 808 tubes in the replacement bundle, all 8 ft. long and ⅞ in. O.D. Stainless ferrules, ¾ in. long, were supplied on the ends of the tubes for rolling into a Type 304 stainless tube sheet.

A new layout pattern was also established for more efficient operation. The final condenser is a fixed-head, single-pass unit with a Type 304 stainless steel tube sheet and shell. All baffles, made of Naval brass, are disk and doughnut type. Holes in the tube sheets have unusually tight tolerances – 0.880 in. (±0.002 in.) – to accommodate tubes of 0.875-in. nominal diameter. There is just 1/32 in. clearance between the O.D. of the tubes and the baffle holes. Over-all design improvements provide more uniform distribution of the cooling water, and better tube support without a pressure drop on the shell side.

Installation of the new exchanger eliminated all of the leaking that *(Continued on p. 128)*

Metals Reinforced With Fibers

By D. L. McDANELS,
R. W. JECH
*and J. W. WEETON**

Experiments with composites made up of tungsten wires in a copper matrix indicate that their strengths are directly proportional to the volume percentages and tensile strengths of the tungsten wires. The authors feel that this relation may hold true when whiskers (tensile strength – 2,000,000 psi.) are used instead of wires. If so, composites with tensile strengths of over 1,000,000 psi. may someday be available. (H17; Cu, W, 14-61)

IN THE FUTURE, composites of different metals or of metals and ceramics may permit the creation of materials that take advantage of the desirable properties of the constituents while minimizing their undesirable properties. One of the newer and more promising materials under investigation today, for instance, is a metallic composite, composed of a metal matrix reinforced with metallic fibers.

To explain further, two types of metallic fibers are available today. One of these is the conventional polycrystalline wire, the other, the whisker. In a true sense the latter are not fibers, but rather are single crystals with great strength due to a high degree of crystalline perfection. For example, the strength of an iron whisker, plotted in the uppermost portion of Fig. 1, may reach a high of 2,000,000 psi., a value which nears its theoretical strength. Sapphire whiskers are around 1,750,000 psi.

The curve also shows the tensile strengths of cold drawn tungsten fibers plotted against their diameters. As the fiber diameter is reduced, the strength increases significantly – in fact, up to as much as 600,000 psi. for very fine wires (0.001 in. diameter). If all or even part of these tremendous strengths could be retained when the fibers were incorporated into an engineering material, a superior product could result.

Many Handling Problems

Due to their very fine size, however, whiskers and fibers are most difficult to handle and to fabricate into specimens. To make a usable product, it is first necesessary to learn how to handle, mix and sinter very fine fibers and whiskers with powders or with liquid metals. It seemed advisable to conduct preliminary experimentation with wires. Since metallic

*Lewis Research Center, National Aeronautics and Space Administration, Cleveland.

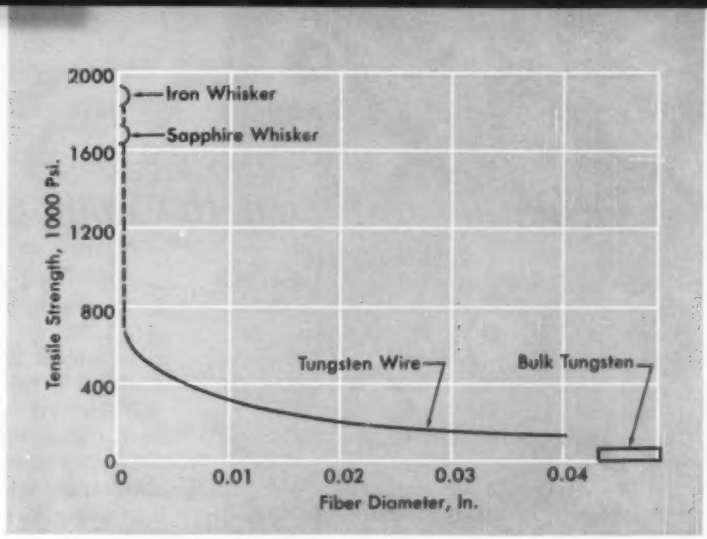


Fig. 1 – Strength of Whiskers and Fibers at Room Temperature. To date, the research at N.A.S.A. has been confined to reinforcements made with fine wires

filaments can be drawn to diameters of 1 mil or less, they may be used as substitutes for whiskers to study mechanisms by which bonding may be accomplished.

Since mutually insoluble metals were desired to avoid alloying effects, tungsten filament wire was selected for the reinforcing fiber and copper for the matrix. Tungsten was also selected because of its high tensile strength and its ability to withstand high temperatures without significant loss of its room-temperature properties. Copper was chosen because of its relatively low melting point and ability to wet tungsten.

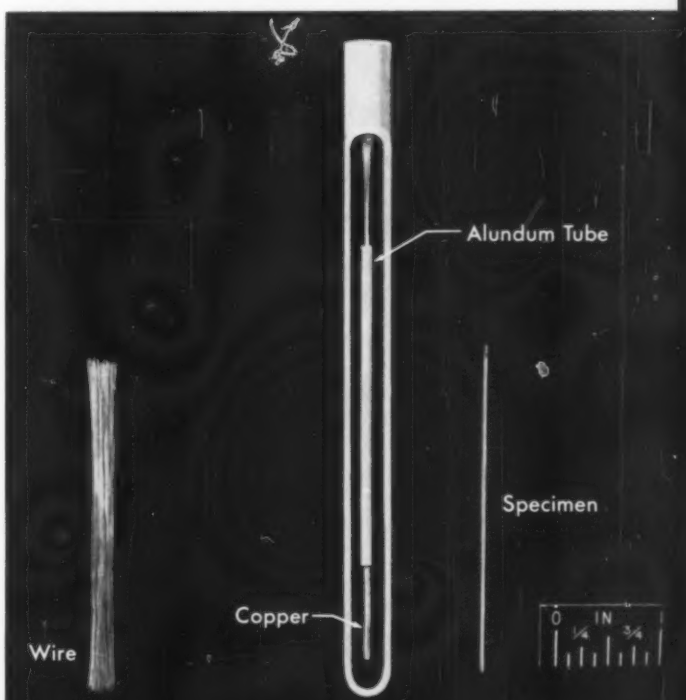
As a first approach small cylindrical specimens, consisting of bundles of fiber which were infiltrated with molten metal, were used. To fabricate test specimens, bundles of tungsten fibers were cut to the length of the specimens to be tested, cleaned with sodium peroxide and ammonium hydroxide, and loaded into an alundum tube. This tube was then placed in a closed-end quartz tube, as Fig. 2 illustrates. The entire assembly was heated to 2200° F. (in a vacuum to prevent oxidation) and held for 1 hr. During infiltration, the spaces between the wires of the thickly packed bundles (see Fig. 3) served as capillary tubes through which the molten copper could flow.

Tensile Testing Follows

For the next step, tensile tests were made of composites which contained different percentages of fibers. In addition, the tensile strengths of the pure copper and the tungsten fibers were determined. The latter were annealed for 1 hr. at 2200° F. to obtain the true strength of the fiber used in the composites (the infiltration process involved this thermal treatment).

The results of room-temperature tensile tests conducted on composites of different compositions are shown in Fig. 4 along with a calculated strength-composition curve (for 5-mil tungsten composites). Thus far, we have tested specimens containing 13 to 77 vol.% fiber. Preliminary tests have been made of composites with 3-mil and 7-mil fiber; these data points are also shown. Since the finer wires have a higher tensile strength, the strengths of the composites vary inversely with the diameters of the reinforcing fibers, increasing with decreasing wire diameter.

Fig. 2 – How the Tungsten-Copper Composites Are Produced. After specimens are assembled, the assembly is heated at 2200° F. to melt the copper; this produces an integral bond between the tungsten wires and the matrix



Calculating the Strength-Composition Diagram

A calculated strength-composition diagram for composites is essentially a plot of calculated strengths of composites with varying compositions. Such a diagram permits one to predict, to some degree, the strengths of a composite, and also serves as a basis for comparison with experimental data.

If a two-component system is considered, it might be expected that each constituent would carry a load proportional to its tensile strength and volume or cross-sectional area. Or, put in another way, the tensile strength of this composite would be equal to the tensile strength (of one constituent) multiplied by the volume percentage of that constituent plus the tensile strength of the other constituent multiplied by *its* volume percentage. In a graph, then, a line drawn between the strengths of any two constituents would give the strength of any composite of any given composition.

However, since we were considering metals with differing tensile strengths, differing moduli of elasticity, and different ductilities, we felt that we could make a more realistic calculation of a strength-composition diagram. To explain further, in compositions varying from pure copper to pure tungsten, it would be expected that there would be instances where either the copper matrix or the tungsten fibers would be the main constituent carrying the load. Each system requires a different treatment. When tungsten fibers carry the major load, the equation is:

$$P = \sigma_C A_C = \sigma_F A_F + \sigma_M{}^* A_M$$ where:

P = load carried by the composite

σ_C = tensile strength of composite

A_C = cross-sectional area of composite $(= 1)$

σ_F = tensile strength of fiber

A_F = fraction of cross-sectional area of composite occupied by fiber

$\sigma_M{}^*$ = stress on copper matrix

A_M = fraction of cross-sectional area of composite occupied by matrix $[= (1 - A_F)]$

The stress on the copper, $\sigma_M{}^*$, is not the ultimate tensile strength of copper in this composite. Instead, it is a stress selected from the stress-strain diagram for pure annealed copper at the final elongation of the tungsten, 1.5% – which, of course, is considerably less than that which the copper can withstand (about 35%). Thus, when the copper in a composite is elongated to only 1.5%, it is stressed well below its ultimate tensile strength – only up to about 8000 psi., in fact.

When the tungsten carries the major load, failure of some of the fibers would result in almost immediate failure of the composite. Why? As a load is applied to the composite, the tungsten fibers carry the bulk of the load. When one or more fibers fail, the load has to be supported by the remaining area of the composite. Since this would increase the unit stress on all remaining fibers and the remaining matrix, essentially immediate fracture would be expected.

On the other hand, where copper supports most of the load, failure of the tungsten fibers would not result in the immediate failure of the composite. In fact, the fibers would fracture when the copper would elongate as little as 1.5% – the elongation of the tungsten fibers at their fracture stress. Immediately after the fibers fail, the load would be transmitted to the remaining copper matrix. The copper would then elongate (up to as much as 35%) until it would reach its ultimate tensile strength and the specimen would fail. In equation form, this is: $P = \sigma_C A_C = \sigma_M A_M$ where σ_M is the ultimate tensile strength of copper matrix, and the area of the copper, (A_M), is equal to the area of the composite, (A_C), which may be expressed as unity, minus that fraction of the area occupied by fibers, A_F.

For in-between situations (where the load-carrying capacity of the matrix and fibers is about equal), the two may be equated as shown below:

$$\sigma_M A_M = \sigma_F A_F + \sigma_M{}^* A_M$$

For composites composed of 5-mil tungsten wire and copper, this composition was calcuated to be 5.3 vol. % tungsten. As Fig. 4 shows, the major portion of the calculated curve (the portion above 5.3% fibers) is straight, having a strength intercept, at 100% tungsten, equal to the strength of the fiber and an extrapolated intercept, at 100% copper (0% fiber), equal to 8000 psi. As fiber content drops below 5.3 vol. %, the curve turns upward and reaches the ultimate tensile strength of copper at 0% fiber.

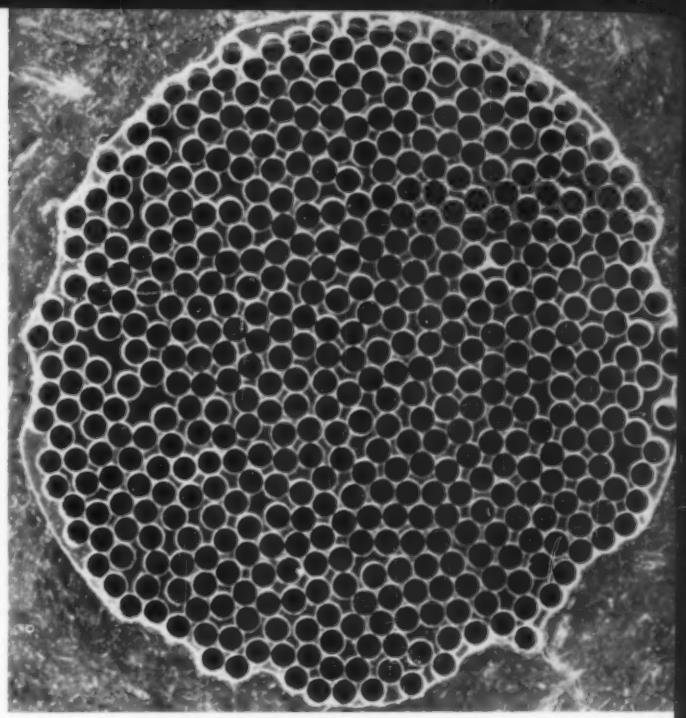


Fig. 3 – Transverse Section of Composite Containing 483 Tungsten Wires in a Copper Matrix. In this research, volumes of tungsten and copper were determined from area measurements (with a planimeter) of such photographs. 40 ×

It will be noted that the strength of the experimental composites falls along the straight portion of a calculated curve. (The calculations are explained in a separate box.) Thus, within the range of compositions studied, the strength of the composite is directly proportional to the amount of reinforcement present.

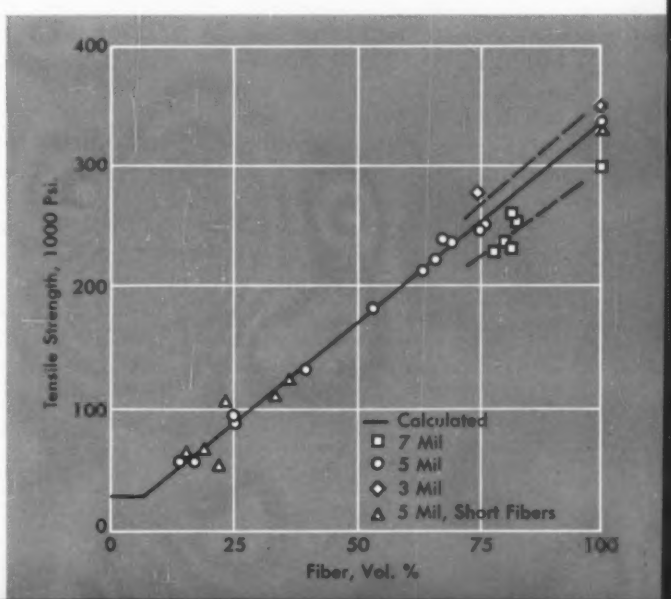
We also investigated the effects of fiber length on the tensile strength of composites. Discontinuous fiber composites were made by packing cut lengths of 5-mil tungsten wire in an alundum tube. The wires, which ranged in length from ⅛ to ⅝ in. (although the majority were about ⅜ in. long), were packed in the tubes so that the long axis of each fiber was oriented parallel to the long axis of the specimen. After infiltrating them with copper (as described for the bundles containing full-length fibers), the specimens were tested. Since the minimum length of the specimens was 1½ in. and the fibers were considerably shorter than the test section, the tests reflected the true effect of short discontinuous fibers in a composite.

The results of a limited series of tensile tests conducted at room temperature indicated that most of the data points fell very close to the calculated curve (see Fig. 4). Thus, the strengths obtained, to date, on discontinuous fiber composites are almost identical to those of specimens with the full-length fibers.

Metallographic examinations of fractured composites showed that the tungsten fibers necked down and that they did not pull out of the copper matrix. Nor did the matrix fracture independently of the fibers. This information seems to indicate that both constituents of the composite fail in tension. If so, each constituent in a discontinuous fiber composite carries a tensile load proportional to the strength and volume percentage of the constituent.

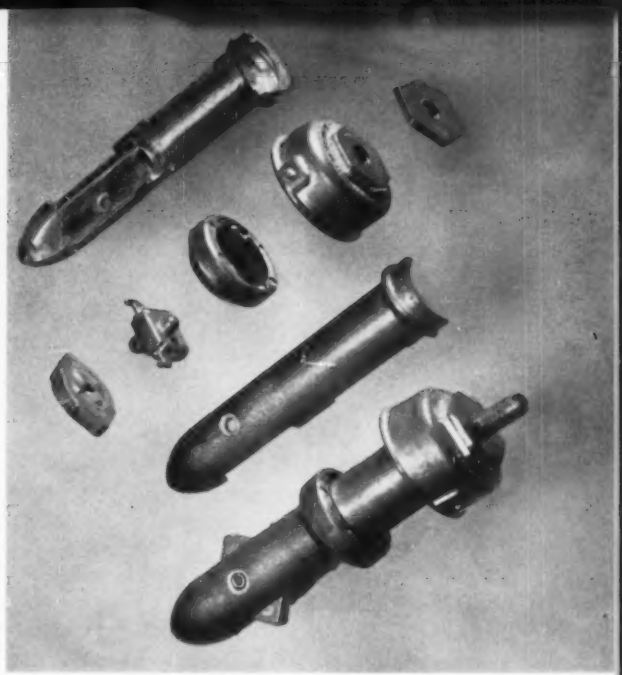
The implications of these results are of considerable interest. One might speculate that if very high-strength whiskers were used as the discontinuous fibers, rather than the wires we employed, the strengths of composites could be increased drastically. For example, if it is assumed that the tensile strength of the fiber were 2,000,000 psi. (a known whisker strength), it may readily be visualized that a composite having a strength of over 1,000,000 psi. could be produced. We are assuming, of course, that whiskers can be used without damaging them, either by mechanically handling or by heating during the fabrication of the specimens. Even if it is found that whiskers cannot be employed for such composites, it is felt that engineers may be able to develop many practical high-strength engineering materials through the use of very high-strength metallic fibers or ceramic fibers as reinforcements for composites.

Fig. 4 – Comparison of Calculated and Observed and Tensile Strengths of Tungsten-Copper Composites. Tests on long and short fibers are shown. Note that there is close agreement. Dashed lines represent data obtained when testing 7-mil and 3-mil wire



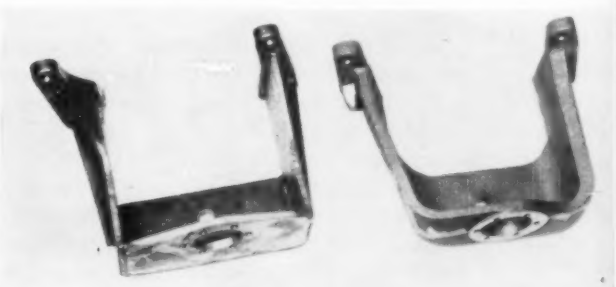
Good Design Pays Off in Zinc and Gray Iron Castings

Emphasis on good design and careful selection of the method by which parts are made can lead to economies in production and a more useful product. Pictured here are castings that were conceived with these ideas in mind. As a result, they won recognition in recent contests sponsored by the New Jersey Zinc Co. and the Gray Iron Founders' Society. (T-general, 17-57; CI-n, Zn, 5-60, 5-61)



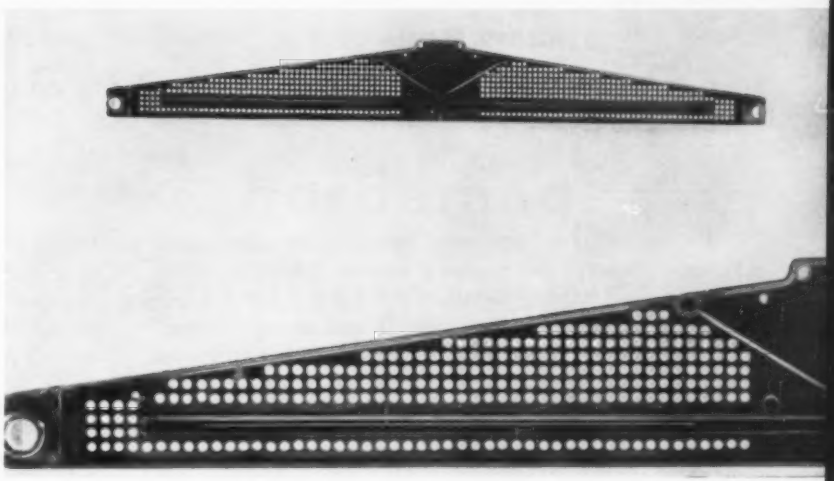
Bobbin holder demonstrates one of the most effective uses of zinc die castings. Made by Whitehead Die Casting Co., Inc., Atlanta, Ga., all parts of the assembly except a spring are zinc. Outstanding cost reduction in a high-volume item is its principal advantage.

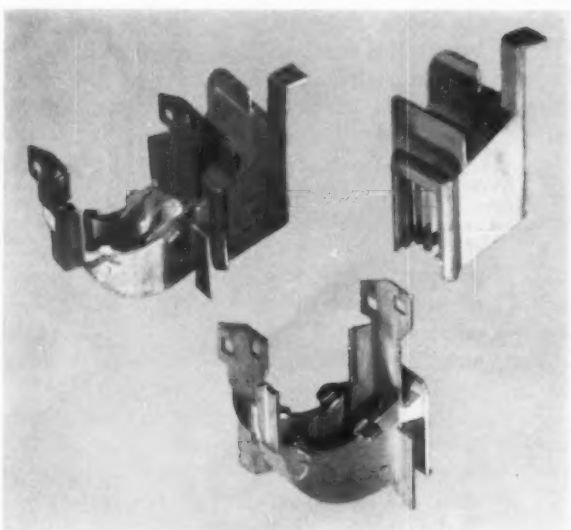
Cost of this engine and hydraulic pump support was cut almost in half by redesigning it as a gray iron (Class 30) casting. It requires only three operations – grinding, drilling and spot facing – to be ready for use. The previous method of fabrication called for about 245 in. of torch cutting and welding of seven parts (left). Casting (right) was designed by Gordon Kousek, J. I. Case Co., Racine, Wis.



Farm implement which transmits load from tractor draw bar to cultivator was strengthened by 20% when redesigned from a welded structure (left) to a Class-40 gray iron casting by Roy Brandt, Oliver Corp., South Bend, Ind. Cost was reduced more than 10%. Consistent dimensions from casting to casting make installation less troublesome. Cast-in locking fixtures also allows assembly to be made with one rather than two wrenches.

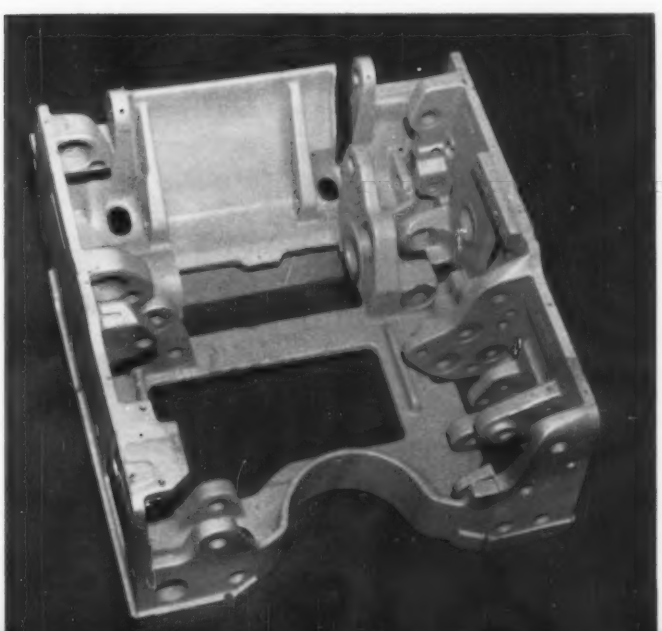
A zinc die casting in a digital tape handler contains 515 cored holes. Previously machined from aluminum, it is cast at a savings of 95% by A & A Die Casting Co., Gardena, Calif. Two 0.007-in. slots running most of the 32-in. length of the part are cast in from one side to about 0.020 in. of the surface, then are milled through. Wall thickness varies from 0.025 to 0.175 in. The casting took top honors in a New Jersey Zinc Co. contest, the prize of $1000 going to Victor O. Anderson for his contribution to the design.





Complex detail and thin walls possible in zinc die castings are apparent in this two-piece unit for a 35-mm. projector. In it slides are preheated so that refocusing is not necessary during projection. Castings are made by Kisiel Die Casting Works, Batavia, N. Y.

Winning entry in Gray Iron Founders' Society Design Contest was this main structural assembly, which was designed by John Douglass of the Shampaine Co., St. Louis. The unit encloses gear and worm drives for an operating table. Use of four castings simplifies fabrication, formerly done by bolting and welding lugs to a single casting, and reduces production costs by $90 per unit.



Short Runs

Treating Waste From Chromium Plating

*By A. J. D'ORAZIO**

IN REMOVING HEXAVALENT CHROMIUM from plating wastes at Pontiac Motor Div., some 400,000 to 700,000 gal. per day of spent solution are treated. This treating unit, along with four others at our plant, must be used before wastes can be discharged to the city's sewage plant.

Basis of the process is the reduction of hexavalent chromium with sulphur dioxide added as a liquid and subsequent precipitation of the chromium as a hydroxide. This method replaces a continuous process employing gaseous sulphur dioxide which had limited capacity. The batch method now used is carried out in large steel tanks lined with Koroseal.

Generally, the waste solution which is to be treated contains less chromium than nickel and copper. During a typical five-day operating period the chromium content varied from 4.5 to 92.5 ppm. About 550 lb. of chromic acid is recovered in the plating plant by ion exchange and vacuum evaporation. Sodium hydrosulphite also helps remove chromium. It is used in rack strip and cleaning solutions to reduce any chromic acid trapped by the plating racks after cleaning and rinsing. This, of course, lowers the demands on the waste treating system.

Treatment is started after one of the holding tanks becomes half filled with the waste electrolyte. Concentrated sulphuric acid is pumped in until the pH drops to 2.5. Sulphur dioxide is then added through a stainless steel diffuser placed directly beneath an agitator which is immersed in the solution. The sulphur dioxide passes from cylinders through a ¾-in. iron pipe to a rotometer. Flow rate to the rotometer (up to 250 lb. per hr. is possible) is controlled by a stainless steel regulating valve. From the rotometer it travels through stainless pipe to the diffuser. Siphoning of the waste through the line is prevented by a stainless steel check valve. The stainless pipe and the diffuser are held in position by plastisol-coated steel rods.

Chromium is reduced according to the following reactions:

$$SO_2 + H_2O \rightarrow H_2SO_3$$

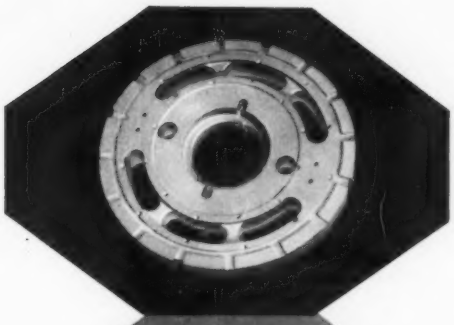
$$2H_2CrO_4 + 3H_2SO_3 \rightarrow Cr_2(SO_4)_3 + 5H_2O$$

Experience has shown that the sulphur dioxide requirements vary from 3 parts to 9 parts per part of chromium. The excess is greatest when the concentration of hexavalent chromium is below 5 ppm. Copper also affects the amount of sulphur dioxide needed. More is required as copper content increases.

After the proper amount of sulphur dioxide is added, the solution is pumped to a polishing tank and the pH is raised by lime additions to about 7.0. The waste is then transferred to a final clarifier where more lime is used to bring the pH to 9.5. At this pH the chromium is precipitated as $Cr(OH)_3$.

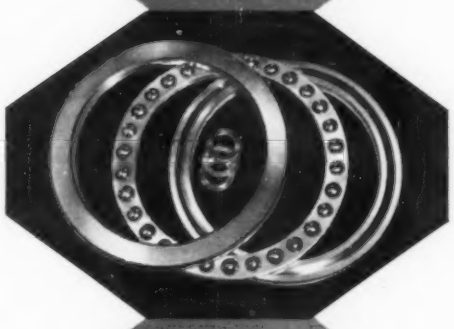
*Assistant Chief Chemist, Pontiac Motor Div., General Motors Corp., Pontiac, Mich. Adapted from a paper presented at the 15th Annual Purdue Industrial Waste Conference.

Fig. 1 — Chromate Wastes From Pontiac Motor Div.'s Plating Lines Are First Treated With Liquid Sulphur Dioxide, Then Transferred to One of Three Polishing Tanks (Center) Where Lime Additions Raise the pH to About 7. Neutralized waste is then pumped to final clarifier (background) where pH is raised to 9.5 thus precipitating the chromium as a hydroxide



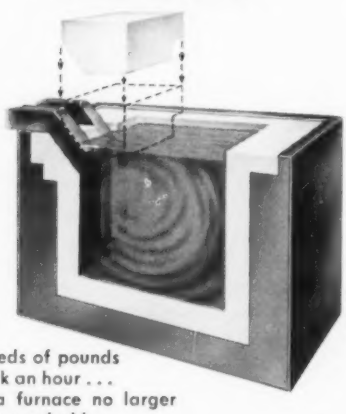
Martempering tamed this heat treater's "nightmare"!

This Vasco B. B. steel valve plate is 11¾" in diameter and varies in section from ½" to 1⅛". Ajax austenitizing and martempering followed by air cool and draw hardens it to Rc 63-64 on the lighter sections and to Rc 60-64 on the 1⅛" section — without cracking, distortion or surface defects.



Assuring bearing race hardness . . . without distortion.

Freedom from distortion and extreme surface hardness are essential to these 52100 steel bearing races. Ajax austenitizing with Ajax cataract quenching plus air cool and draw supply these characteristics in full measure—on a fast production basis.



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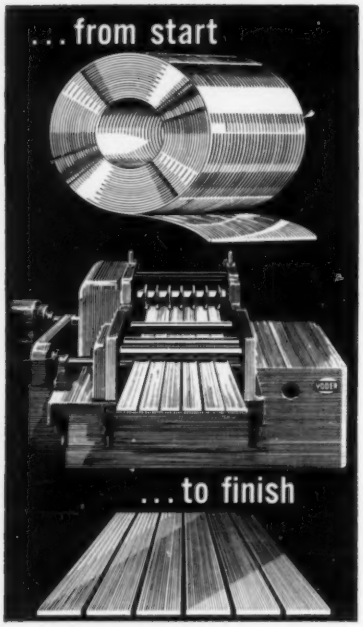
Circle 2369 on Page 48-B



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ENGINEERING YODER MANUFACTURING ROTARY SLITTING LINES

Circle 2370 on Page 48-B

Testing of Tubing . . .

(Continued from p. 114)

crystal transmitter. The surface of the tubing acts as a mirror for the sound waves, bouncing them back and forth between the O.D. surface and the I.D. surface. To inspect tubing, the "shear" technique is used. The pulse is introduced at an angle, and echoes back and forth between the outer and inner surfaces around the circumference of the tubing. If there are no cracks or flaws in the tubing, the sound wave ends up as a straight line on a cathode ray oscilloscope; if there are flaws, they will show up as a jagged line or "pip".

In performing the test, the tubing is revolved while the pulse generator moves along its length. In another version of the test, the tubing is immersed in a tank of water with the water acting as a couplant. For tubing, the latter method seems to give better results than contact ultrasonic testing, apparently because there are fewer false indications.

Ultrasonic testing has an advantage over eddy current testing (as now developed) in that it can be used for either magnetic or nonmagnetic metals. Like eddy currents, ultrasonics will detect O.D., I.D. and subsurface defects. Considerable skill is required to set up the equipment, but interpretation of results is not subject to the operator's judgment if an alarm circuit is used. Equipment is expensive.

As for drawbacks, ultrasonic testing is fairly slow, and it will not test tubing satisfactorily in the smaller sizes. If the tubing is less than ½ in. O.D. or has a wall thickness under 0.049 in., we consider it impractical to test by ultrasonics.

Other disadvantages: Diagonal laps which parallel the sound wave can be missed; surface reflections can also cause interference, and the defect's location (whether O.D. or I.D.) cannot be determined.

While ultrasonic testing is useful as a further check on other nondestructive tests, it is not as sensitive as the dye penetrant or eddy current tests on tubing ½ in. or less in diameter. If nonmagnetic materials are being tested, our experience has shown that eddy current is superior to ultrasonic testing.

In radiographic inspection, X-rays are generally used, but radioactive isotopes such as cobalt-60, iridium-90 and thorium-170 have also been employed. The isotopes emit gamma rays which give greater penetration. As the rays pass through the steel, the densest portions of the metal absorb the most rays; internal defects show up as dark spots on the developed photographic film.

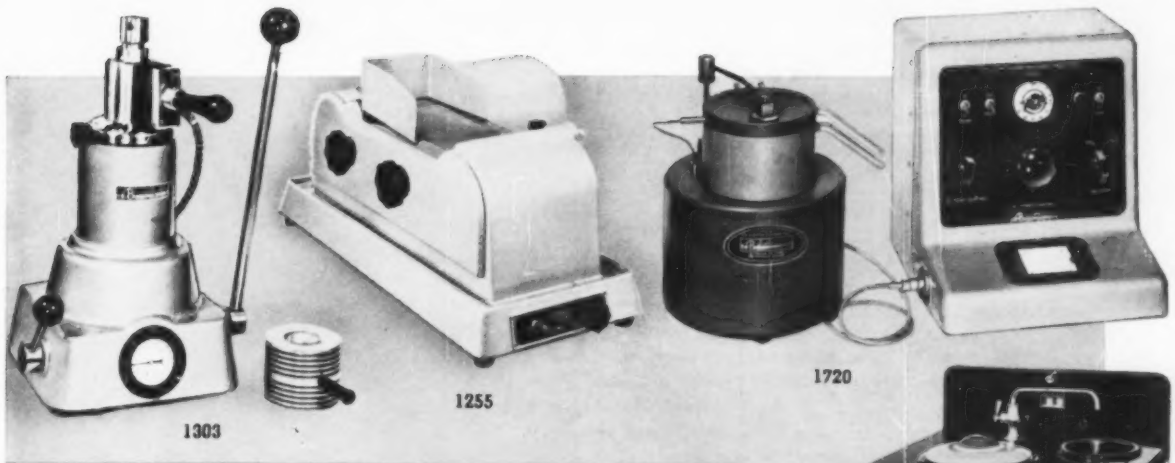
Considerable skill is required to interpret the radiographic film. As a check on the adequacy of the radiograph, a standard test piece called a penetrameter is often used. The radiographic technique is considered satisfactory if the outline of the penetrameter shows clearly in the radiograph. Film strips showing natural or artificial defects are used as standards to aid in evaluating radiographs.

Normal radiographic checking involves placing film in contact with the inside surface of the tube. Space is a limitation since film cannot be satisfactorily inserted and held in place if the I.D. is less than ½ in. When smaller sizes are to be tested, the only practical approach is to place the tubes on flat X-ray film and take three pictures at 120° angles of rotation. This has the inherent drawback of attempting to interpret effects of penetration through varying wall thicknesses.

Other disadvantages include the high cost of equipment, the need to shield personnel from radiation, and possible interpretation of defects in the film as defects in the metal.

Radiographic testing is valuable in finding gross defects in large sections of metal but, in our experience, has little application in testing small tubing because of its high cost compared to the unit value of the product being examined.

Hydrostatic testing is an internal pressure test. Strictly speaking, it is not a nondestructive test since it may weaken a tube which contains defects without actually bursting it. It is useful in finding open, through-wall defects, because the oil or water will leak through. Generally, all tubing for pressure applications – including super pressure, hydraulic and capillary tubing – is given a hydrostatic test. But it is a capability test only; it will not tell accurately what will happen to the tube in service because the tubing cannot be tested for that length of time. It is limited to finding defects which



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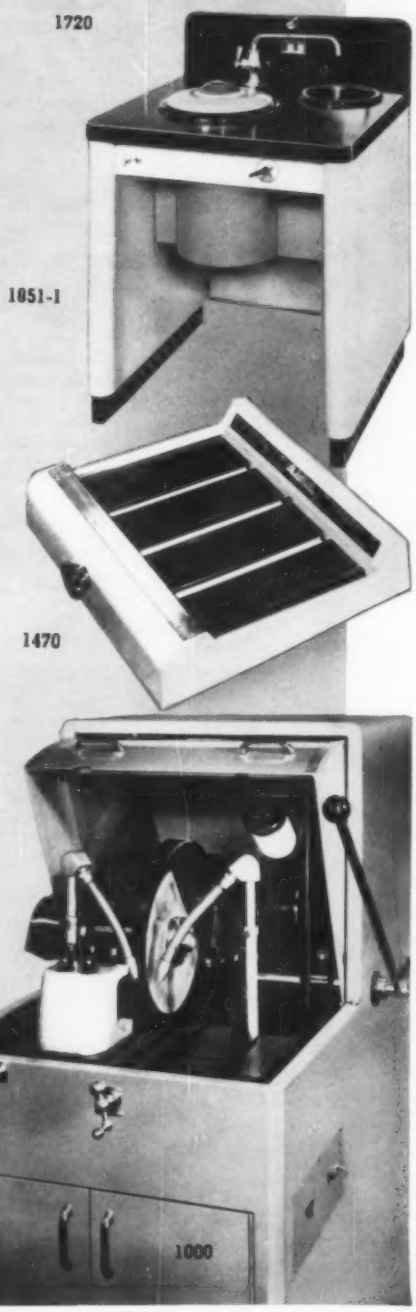
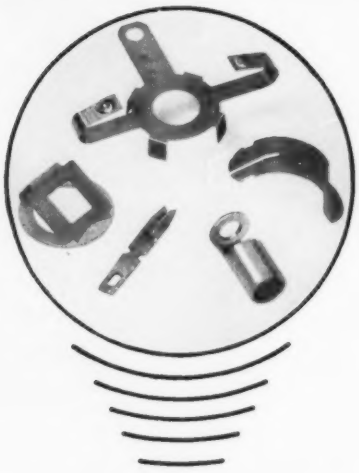


Circle 2371 on Page 48-B

MORE BOUNCE TO THE MILLIGRAM



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Circle 2372 on Page 48-B

Testing of Tubing . . .

penetrate the tubing wall or which will penetrate it when pressure is applied. The cost of the test is comparatively high because of the slow rate of testing.

As a sidelight, we have found that two testers – one supplying up to 20,000 lb. pressure with oil and one up to 40,000 lb. pressure with water – meet nearly all the hydraulic testing requirements for small tubing.

It will be noted from this discussion that no nondestructive tests (except hydrostatic testing) have been developed specifically to test small tubing. Instead, we have adapted nondestructive tests used for other forms and sizes of metal – and this is the basic weakness of the tests now in use. For in these tests, certain physical phenomena – such as sound waves, magnetic currents, and X-rays – are affected by the total size of the flaw (length, width and depth), yet the seriousness of a tubing flaw is almost always evaluated by its effect on the tubing wall; that is, its depth. When a flaw is found, the usual practice is to file it off the tubing (if it is on the outside surface). If the tubing is still within wall thickness tolerance limits, it is accepted; if not, it is rejected. Obviously, much time could be saved by a test which will quickly and accurately measure the depth of the flaw, and determine at once whether it is a rejectable defect.

Nondestructive testing is an extremely valuable tool in maintaining quality control, but it is not an end in itself. Rather it serves to point out questionable features which may be investigated further by destructive tests. If there is one outstanding conclusion we have drawn from our experience in the nondestructive testing of tubing, it is that no one test is sufficient in itself. None of them alone will give the complete answer for all types of tubing under all circumstances.

In conclusion, until such time as a universally acceptable nondestructive test for tubing can be established, the most satisfactory answer to the problem is to *(a)* set up standards for the tests now available and *(b)* establish mutual agreement between vendor and user on exactly what is required of the tubing, what constitutes a defect (rejectable imperfection) and what does not. These are first steps in selecting the best possible test or combination of tests for a given requirement, and they will help to make the most effective use of the tests now available.

Bimetallic Tubing . . .

(*Continued from p.* 117)

occurred with the bare Type 304 stainless tubes. The condenser has been in operation without interruption for more than 18 months.

As shown in Table I (p. 117), bimetallic tubes, which combine stainless steel with a copper-base alloy, are more expensive than solid tubes of either material. But they offer a dependable and economical means of simultaneously handling corrosive materials such as crude organic chemicals, ammonia, wet carbon dioxide and brackish cooling water. Bimetallic tubes are the most plausible way of doing the job in the presence of chloride ions at high temperatures. Under such conditions, brass or copper is needed for the water side to prevent ruinous stress-corrosion cracking.

Other highly alloyed nonferrous materials may satisfactorily handle certain dual corrosive conditions, but they will cost even more than the bimetal tubes of stainless and copper or admiralty. There is one other alternative. The cooling water may be treated to such an extent that a bimetallic tube is not needed. The cost of doing so in a marine location, however, is prohibitive.

Where the process fluid or gas is only mildly corrosive, there is a natural tendency to consider carbon steel in combination with a copper-base alloy. As a rule, these metals make a poor combination. Since the copper tube wall is ordinarily quite thin – about 0.035 in. – it is quite easily perforated during the assembly of the tube bundle. The perforation permits galvanic action between the copper and carbon steel, thus creating an active corrosion cell.

Conversely, a hole in the copper or brass used with the passive stainless steel causes no problem because the electromotive difference between the copper or brass and the passive stainless steel is relatively small.

Bimetallic tubing of stainless steel and copper or brass is mechanically bonded to form a single, uniform

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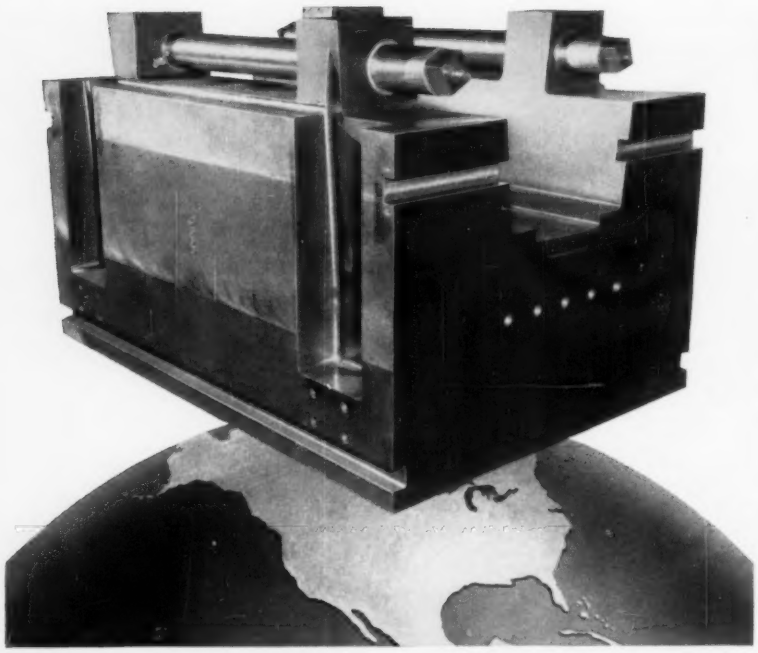

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Circle 2374 on Page 48-B

Bimetallic Tubing . . .

structure. It is produced by placing one tube inside the other and cold drawing both through a die to the specified finished size. Inner and outer tubes are separately processed to the required physical and mechanical properties. Prior to bonding, the stainless and the dissimilar tubes are completely inspected and tested to assure soundness.

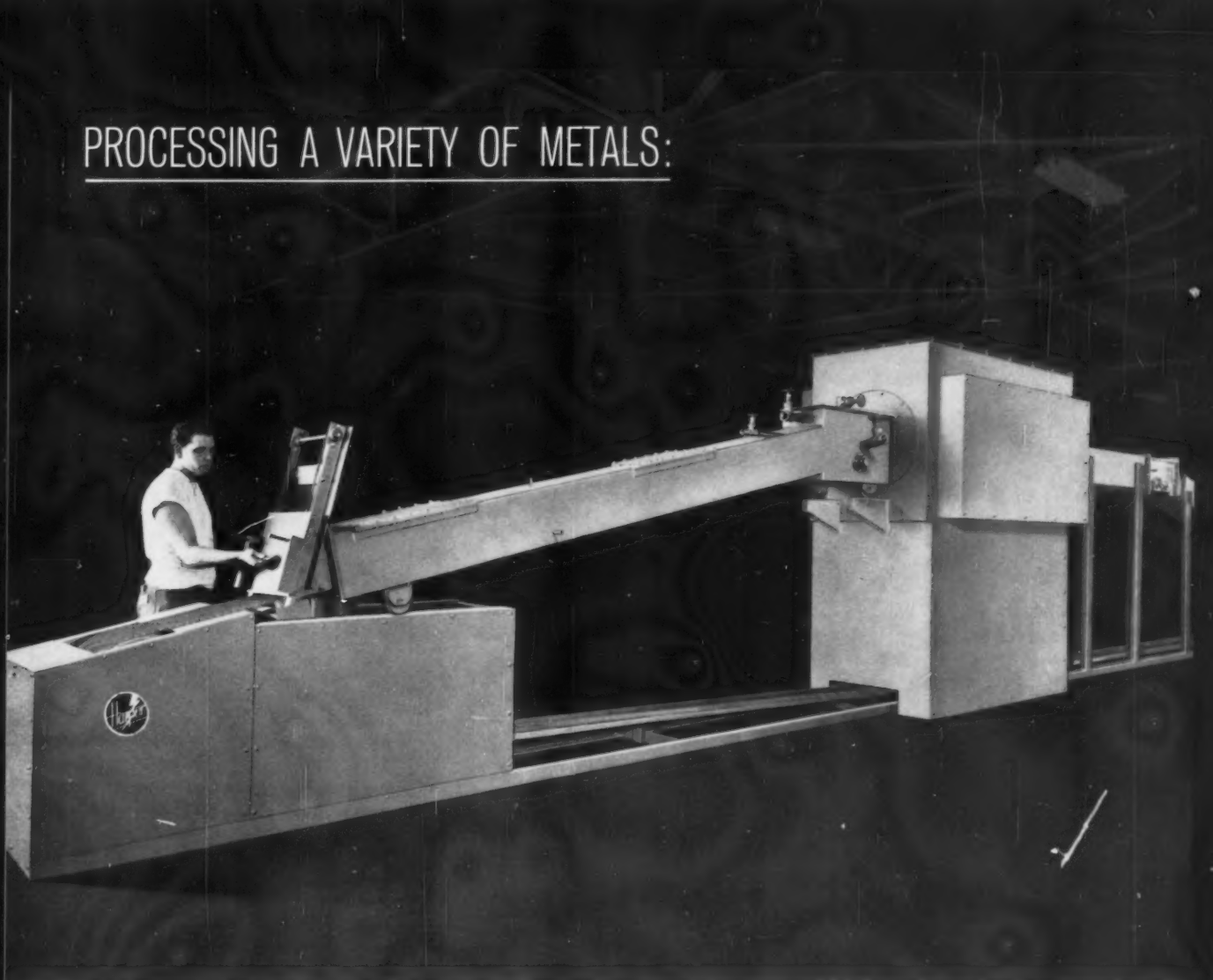
Bimetallic tubes are available in all normal sizes for heat exchangers. Special sizes can be supplied for heat exchanger service on special orders. Wall thicknesses can be provided in the combinations most suitable for specific service conditions. Care must be taken in specifying the proper gages for replacement tubes so that there is no reduction in I.D. which would reduce throughput. Wall tolerances for bimetallic tubing are somewhat greater than for austenitic stainless steel.

Mechanically bonded, dissimilar tubes can be satisfactorily formed into hairpin or U-shapes which are frequently required for compact design and heat exchange involving wide differences in temperature. They can be readily machined or threaded.

In any bimetal tube, one or the other of the tube walls must be thick enough to withstand the operating pressure. If we assume, as is generally true, that the stainless tube must be heavy enough to carry this load, then the heat conduction through the wall of the bimetal tube will always be less than through an all-stainless tube.

Heat transfer is also affected by the quality of the bond between the two metals. If the bond is good, it offers negligible resistance to heat transfer compared to that caused by films and fouling encountered in most heat exchanger designs. Although the bimetal tube, compared with a single metal tube, is substantially less efficient in heat conduction, the over-all heat transfer effect in the exchanger is essentially the same provided the tubes are bonded satisfactorily. This is because the resistance to heat flow in a solid wall tube or a well-bonded bimetal tube is usually insignificant compared to the remaining resistance to heat flow encountered in the fluid films and fouling on both sides of the tube.

PROCESSING A VARIETY OF METALS:



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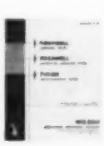

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Circle 2376 on Page 48-B

Bimetallic Tubing . . .

The heat transfer efficiency of bimetal tubes is generally satisfactory if there is a good bond along the full length and surface between the two metals. With perfect contact between the two metal surfaces, the heat transfer rate through bimetallic tubes of 16-gage wall thickness is about 29% better than that of 16-gage stainless. The perfect tube, however, is not the average product. For practical purposes, calculations should be based on results obtained with a good-quality bimetallic tube.

Generally speaking, a stainless steel tube has better heat transfer efficiency than a good-quality bimetallic tube of stainless and deoxidized copper or admiralty. How much better depends on surface cleanliness. A clean 16-gage bimetallic tube with bond resistance of 0.001 hr. per sq.ft. per °F. per Btu., will have 25% to 40% of the heat transfer of the bare 16-gage stainless tube. Bond resistance is the reciprocal of the bond heat transfer coefficient which is expressed as Btu. per hr. per sq.ft. per °F. temperature difference. Bond resistance then indicates the time necessary to transfer 1.0 Btu. through 1.0 sq.ft. of bond surface when the temperature difference is 1.0° F.

While it is important that the bimetallic tubes have a near-perfect bond, it is also essential to heat transfer efficiency that the inner and outer surfaces of the dissimilar metals be as clean as possible.

The following table compares the heat transfer of an average bimetallic tube, having a good bond and under varying cleanliness conditions, with that of an average bare stainless tube having a clean surface:

Surface Cleanliness		Heat Transfer (% of Bare Tube)
Side 1	Side 2	
Excellent	Excellent	25 to 40%
Good	Excellent	15 to 20
Good	Good	10 to 12
Poor	Excellent	6 to 8
Poor	Poor	1 to 3

Also helpful to better heat transfer is the use, where possible, of high-velocity water or condensing steam. Even though bimetallic tubes are substantially less efficient than those of stainless steel, it is usually a simple matter in design to get the temperature you need by increasing the tubular surface.

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Circle 2377 on Page 48-B

CORRESPONDENCE

Our Mistake!

In our November issue, under the heading "More Interest in Direct Iron Processes" (Technical News in Brief, p. 67), we inadvertantly gave Mexico a commanding lead in the race for more iron production. According to our story, Hojalata y Lamina is going to build a "300,000-ton-per-day" plant for direct iron production. This would indeed be noteworthy news. These figures, projected for a full year, show that this one plant would be making almost 100,000,000 tons per year — a production nearly equal to the full capacity of the United States. Needless to say, the actual figure is "300,000 tons per *year*".

Metallurgy Versus Linguistics

VOLTA REDONDA, BRAZIL

In "Press Breaks", *Metal Progress* for March 1960 (p. 5), the Editors ask for information about polyglot dictionaries in the field of metallurgy — a matter of bread-and-butter importance to such as the writer of this letter, whose associates ordinarily use the Portuguese language. The following items may therefore be a real help to one seeking help on the Metallurgy versus Linguistics battlefield.

As I know from experience, there exist at least two excellent metallurgical dictionaries compiled by and for metallurgists, the one being Köhler-Legat: "Wörterbuch für die Eisen und Stahlindustrie" (English-German and German-English), published by Springer, Vienna, Austria, 1955, 330 p. ($7.00).

The other is a result of the combined effort of the Verband Deutscher Eisenhüttenleute and the (British) Iron and Steel Institute: "Stahleisen Wörterbuch" (German-English and English-German), published by Verlag Stahleisen, Düsseldorf, West Germany, 1958, 272 p. ($3.00).

An excellent general technical and linguistic work in the German and English domain is "Das Englische Fachwort", by H. G. Freeman, 7th Edition, published by Girardet, Essen, West Germany, 1955, 498 p. ($7.50). This book (written for the German engineer) contains plenty of excellent metallurgical passages, explaining all English and German words in their natural habitat, and includes illustrations of both American and British usage with exact German paralells. It also contains a very extensive English-German and German-English glossary of words whose translation give most of the headaches.

Engineers having a working knowledge of metallurgical German can have fairly easy access to Russian literature by a good metallurgical dictionary prepared by a professional metallurgical translator, Fritzsche: "Wörterbuch des Hütten und Walzwerkwesens" (Russian-German), published by Verlag Technik, Berlin, East Germany, 1955, 387 p. ($9.00).

A fine four-language glossary of terms concerning steel structures has been published as an appendix to the third volume of "Stahlbau" of Köln, West Germany, 1959. It is in German, English, French and Spanish, and has a total of 129 pages.

The publishing firm of Elsevier, Amsterdam, Netherlands, is announcing a multi-language metallurgical dictionary (English, American (!), French, Spanish, Italian, Dutch, and German, with definitions given in English), compiled by W. E. Clason, head of the translation department of Philips' Lampworks. Knowing the very high quality of the metallurgical publications of that company, published simultaneously in various languages, it must be assumed that this new book will become a good dictionary for the metallurgist.

People interested in the Swedish metallurgical literature will find excellent help in the publications of T.N.C. Tekniska Nomenklaturcentralen, Stockholm 5, Sweden. This is the Swedish Board for Technical Terminology and it has a fine series of glossaries (partly also in English) on various fields, including metallography and on foundry practice.

A few years ago the Italian Metallurgical Association's journal, *La Metallurgia Italiana*, published a very appreciative review of a book which I have not used but which apparently gives great emphasis to metallurgical aspects: "Dizionario Tecnico" (English-Italian and Italian-English), by G. Marolli, published by Le Monnier, Florence, Italy, 6th Edition, 1290 p. ($17.00).

The "translation" of codes, standards and the like is a more difficult matter. As far as I know there exists but one work entirely dedicated to

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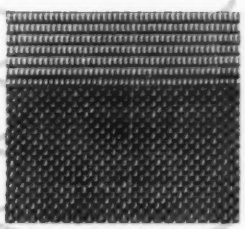
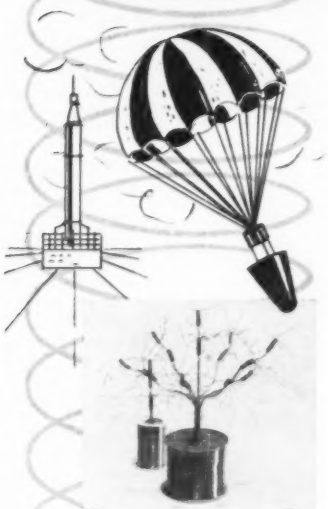


Take ultra fine filters, for instance. For years, weavers of this finer-than-hair material—with over a million openings per square inch—suffered unduly from breakage while fabricating or testing the filter cloth. Rejects were high, and production speed, slow. FWM's research revealed that tiny inclusions in the wire caused the trouble. New methods of wire testing and selection, devised by FWM, are now saving a great deal of money for precision weavers. This type of FWM wire is now the industry's most reliable and most uniform in high quality.



Take space capsule recovery problems, for instance. No organic fabric could stand the friction heat generated, as a capsule parabrake opens at the edge of space to slow and orient the capsule on its earthward descent. FWM developed drawing methods for high temperature fine alloy wire, which, when woven into parabrake cloth, provides more drag than organic fabric and maintains its strength at temperatures up to 1800°F.

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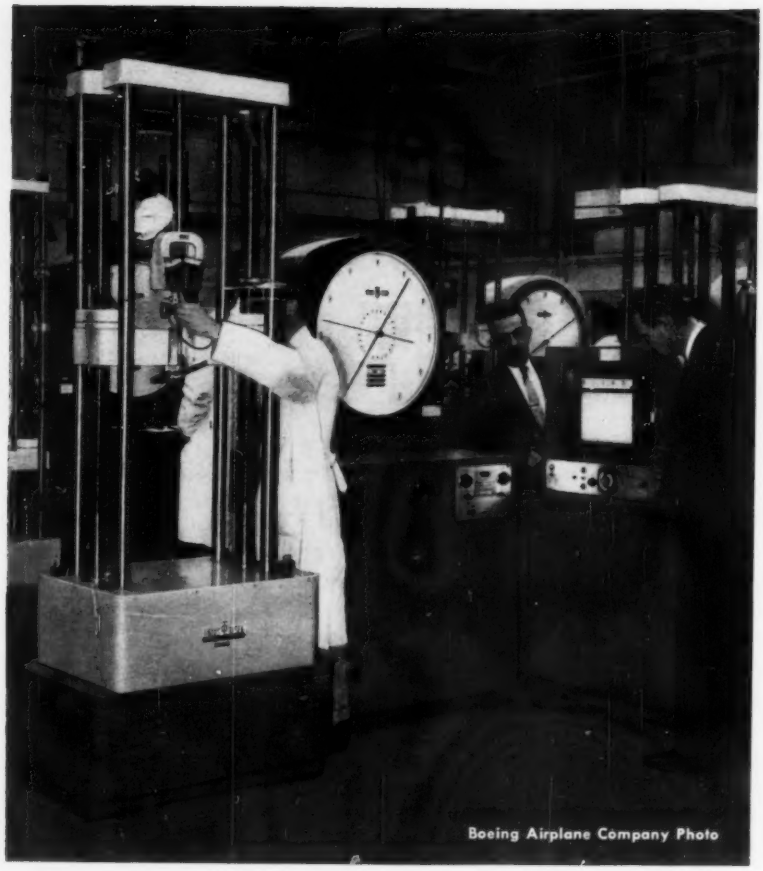
Circle 2378 on Page 48-B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Testing and Balancing Machines

Circle 2379 on Page 48-B

Correspondence . . .

this: "Comparison of Standard Steel Qualities of the World", published about 1953 by the State Publishing House for Technical Literature (S.N.T.L.), Prague, Czechoslovakia. This is an excellent compilation of American, British, French, Russian, German and Czechoslovakian steel designations and standard qualities, giving their composition and mechanical properties in a way that it is usable even without the slightest knowledge of the Czech language.

A similar publication is advertised by Verlag Stahleisen, Düsseldorf, West Germany, as being in preparation: "Die Normstahle der Welt", approximately 300 pages.

Of course, the final solution of all linguistic difficulties might be to learn the A.S.M. Machine Language developed by Professors Kent and Perry, and then to train our fingertips to convert magnetic tape impulses directly into brain waves while passing the tape between the fingers!

LIVIUS MARIA BOTAR
Technical Information Officer
Brazilian National Steel Co.

Gone Fishing

PHILADELPHIA

In the past, there has been considerable hunting for metallurgical dragons and dragonflies in the correspondence columns of *Metal Progress*. I tried fishing and came up

with the metallurgical angel fish shown above. The "fish" is a columbium carbide eutectic of as-cast Type 347 stainless, photographed at 1000 ×.

MELVIN BRODY
Drexel Institute of Technology

SUPERIOR CASTINGS, EXTRUSIONS, TRACED TO USE OF ACHESON COLLOIDAL GRAPHITE

The excellent lubricating properties of these materials have been proven under the severe conditions attendant to aluminum permanent molding and extruding. In the specific examples described below, smoother surface finishes, longer die life, and more uniform metal flow are chiefly attributed to the application of a 'dag' brand dispersion.

Fewer rejects, consistently higher quality castings are obtained at Paragon Aluminum Corporation by spraying 'Prodag' on their permanent molds as a pre-pour wash.

Better surface finish with Prodag® permanent mold coating is just one of the reasons why Paragon Aluminum Corporation, a Division of Detroit Harvester Company located at Monroe, Michigan, switched to this Acheson product. After four years of experimentation with other mold washes, Paragon chose 'Prodag' — Acheson semi-colloidal graphite in water — and has used it constantly the past seven years. The reasons for its choice are these: uniform consistency, excellent heat-transfer quality, and its hard, smooth, tenacious film which resists flaking and provides easier parting characteristics.

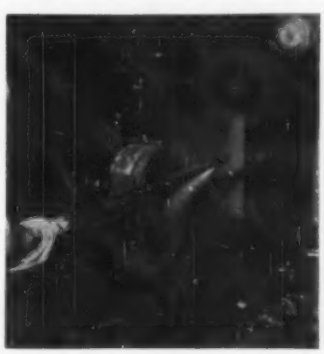
With about 95 per cent of its annual output of more than two million pounds of castings going to the automotive industry, Paragon must insist upon quality. 'Prodag' helps to maintain this standard. Parts for convertible automobile tops are precision-molded from both 355 and 319 aluminum alloy. Molds are pre-heated before each day's run to 600° F. and the casting cycle maintains this temperature. The 'Prodag' dilution ratio is 1 to 4 parts water and is applied to the molds with a commercial spray gun. Aside from occasional touchup at points of greatest wear, this coating lasts through the entire run. Because of the physical contours involved in these comparatively small, light castings, they require rapid cooling in certain areas to insure uniform strength. The 'Prodag' coating — with its proven fast heat transfer ability — allows the castings to cool without breaks or pinholes. And by parting more easily, the high-finish castings which result have given Paragon Aluminum products wide acceptance in this demanding industry. If you have a metal casting problem, write direct for additional information contained in our Bulletin No. 425. Address Dept. MP-120.

'dag', 'Aquadag', and 'Prodag' are trademarks registered in the U.S. Patent Office by Acheson Industries, Inc.

FASTER APPLICATION, LESS MATERIAL USED IN THIS EXTRUSION APPLICATION

Aluminum Extrusions, Incorporated, of Charlotte, Michigan, has realized a 30% savings in their material handling costs by the use of Aquadag® — Acheson colloidal graphite in water. They formerly had used an oil-graphite mixture which required a dilution ratio of 16 lbs. of graphite to a 55 gallon drum of oil. It was too slowly applied by swab and too coarse to effectively apply by spray.

With 'Aquadag', Aluminum Extrusions has a lubricant that is finer in particle size, permits wider coverage, and provides greater "sprayability". These minute particles pass freely through the spray nozzle, eliminating the costly downtime formerly involved in cleaning clogged equipment. The tough, dry film 'Aquadag' forms upon the evaporation of its water carrier, doesn't smoke or react when applied to hot dies and metals. This improves working conditions as well as extends die life. Important also to both die surfaces as well as the finished extrusion, is the fact that this durable, low-friction film allows easier, more uniform metal flow.



Acheson 'Aquadag', applied on die surfaces provides faster, more uniform application for Aluminum Extrusions, Incorporated.

If your problem is more effective lubrication under normally adverse conditions of extreme temperature, pressures, or abrasions, call in Acheson. In the meantime, write for your free copy of Bulletin No. 426.

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Circle 2380 on Page 48-B

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PERSONAL MENTION

Robert B. Mears

ROBERT B. MEARS has been named assistant vice-president, applied research, for U. S. Steel Corp. in Pittsburgh. Dr. Mears' former post as director of the Applied Research Laboratory in Monroeville, Pa., has been filled by **J. G. Donelson**, assistant director, applied research.

After receiving his B.S. degree in electrochemical engineering from Pennsylvania State University in 1928, Dr. Mears joined Bell Telephone Laboratories in New York where he was a member of the technical staff and leader of the corrosion testing group. In 1932 he went to England to continue advanced studies and research at Cambridge University obtaining his Ph.D. degree in metallurgy three years later. On his return to the United States, he became chief of the chemical metallurgy division of the Aluminum Co. of America's research laboratories, New Kensington, Pa.

His association with U. S. Steel began in 1946 when he joined the Carnegie-Illinois Steel Corp. as manager of the research and development laboratory. He held that position during the successive mergers which resulted in the formation of U. S. Steel Corp.

Vincent J. Coppola

VINCENT J. COPPOLA has opened a consulting firm, known as Metallurgical Consultants, in Houston, Tex., to assist manufacturing firms with metallurgical problems relating to heat treatment, alloy selection, corrosion and failure analysis.

A 1943 graduate of the University of Alabama with a degree in ceramics and metallurgy, Mr. Coppola served in the Navy during the war years, then worked for the National Bureau of Standards as a metallurgist; in 1949 he joined the faculty of Iowa State College as an instructor in physical metallurgy. His experience in industry includes six years with Boeing Airplane Co. as quality control engineer and one year as assistant factory metallurgist for Solar Aircraft. In 1958 he went to Cameron Iron Works in Houston as metallurgist, rising to assistant chief metallurgist for the commercial products division before he resigned last summer.

Howard O. Beaver – from manager of mill metallurgy to assistant general superintendent at the Carpenter Steel Co. in Reading, Pa. He is chairman of the Lehigh Valley Chapter.

Simon A. Greenberg

SIMON A. GREENBERG, for 15 years technical secretary of the American Welding Society, and more recently on the engineering staff of Westinghouse Atomic Power Div., has resigned and has an office in Flushing, N. Y., as consultant to metal-using industry on manufacturing methods, inspection, quality control and in-plant training. He has been a prolific contributor to the literature on welding, both as an author of special articles and as a contributor to books. In 1955 he was sent to Europe by the American government to help improve productivity of backward industry.

Earl W. Mahaney – from chief metallurgist of Youngstown Sheet and Tube Co.'s Indiana Harbor Works, East Chicago, Ind., to superintendent of the new quality control department, Chicago district. Other appointments include: **L. Ira Stead** chief chemist, quality control; **Robert A. Dahlberg**, supervisor, quality control, tube mills; **I. A. Sirel**, supervisor, quality control, open-hearth and rolling mill; **W. J. Sperko**, supervisor quality control, hot and cold sheet products; **John F. Wolfe**, supervisor, quality control, tin products.

FAHRITE

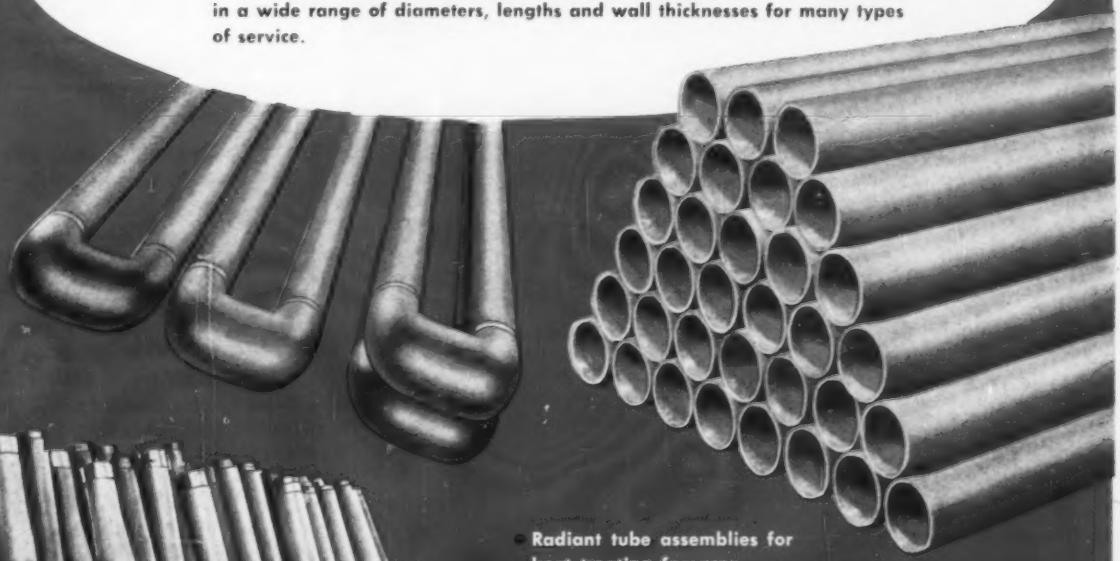
HEAT AND CORROSION *Alloys*

CENTRIFUGALLY-CAST *tubes*

AVAILABLE IN

VARIETY OF LENGTHS AND DIAMETERS

Produced in permanent molds to obtain uniform soundness throughout. Fahrite alloy tubes (in heat and corrosion resistant analyses) are available in a wide range of diameters, lengths and wall thicknesses for many types of service.



- Radiant tube assemblies for heat treating furnaces
- Roller shaft assemblies
- Tubular hearths for batch furnaces
- Hold down roller assemblies for pickling operation
- Sleeves and other uses

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Plants at Springfield and Lima, Ohio SPRINGFIELD, OHIO

New efficiency means you can now handle many mixing jobs with a smaller model drawing less power.
New shock-protected internal gear turns the mixer shaft at a slower, more powerful 350 rpm.
New super-pitch prop delivers up to 45% more fluid flow than previous LIGHTNIN gear-drive models . . . higher impeller head in direct-drive models.
ANNOUNCING

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You get more work out of these all-new LIGHTNIN propeller-type mixers.

They'll handle bigger batches, heavier materials, or do the job faster —*without using more power.*

Often a smaller, lower-cost model will do the job you want done—*on less power than you've been using.* That's how efficient they are.

In normal use, you won't have to lubricate these mixers for five years. Overloads can't hurt the gear drive. The chemical plant motor is standard, at no extra cost.

Notice how we've moved the lower shaft bearing and chuck up out of the mixer base, away from the splash of tank contents. And you don't need three hands to change the shaft. New quick-acting chuck locks it tight when you turn one screw.

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FOR CLOSED TANKS. Same all-new design, with new stuffing box or rotary mechanical seal. Also described in Bulletin B-521.

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MIXING EQUIPMENT Co., Inc., 171-n Mt. Read Blvd., Rochester 3, N.Y.

In Canada: Greey Mixing Equipment, Ltd., 100 Miranda Avenue, Toronto 19, Ont.

Circle 2382 on Page 48-B

Personals . . .

J. C. Hoff – from midwest sales manager to general sales manager for the Kawecki Chemical Co., Boyertown, Pa.

Richard L. Hoff – from senior engineer, Aerojet-General Corp., to development metallurgist, Superior Tube Co., Norristown, Pa. He formerly held the same position, but left Superior for nearly a year to work at Aerojet.

Richard J. Dvorak – from research metallurgical engineer in charge of foundry operations, to sales engineer for WaiMet Alloys Co., Dearborn, Mich.

Leon E. Jeanneret – retired as manager of welded tubing sales for Babcock & Wilcox Co.'s Tubular Products Div., Alliance, Ohio, after 43 years.

Homer D. Gebauer – from district manager in Houston, Tex., to district manager in Pittsburgh for Chase Brass & Copper Co., Waterbury, Conn.

Howard J. Middendorp – from high-strength metals section, physical metallurgy branch, materials center, to the Dynasoar Weapons Systems Office, Wright Air Development Div., Wright-Patterson Air Force Base, Ohio.

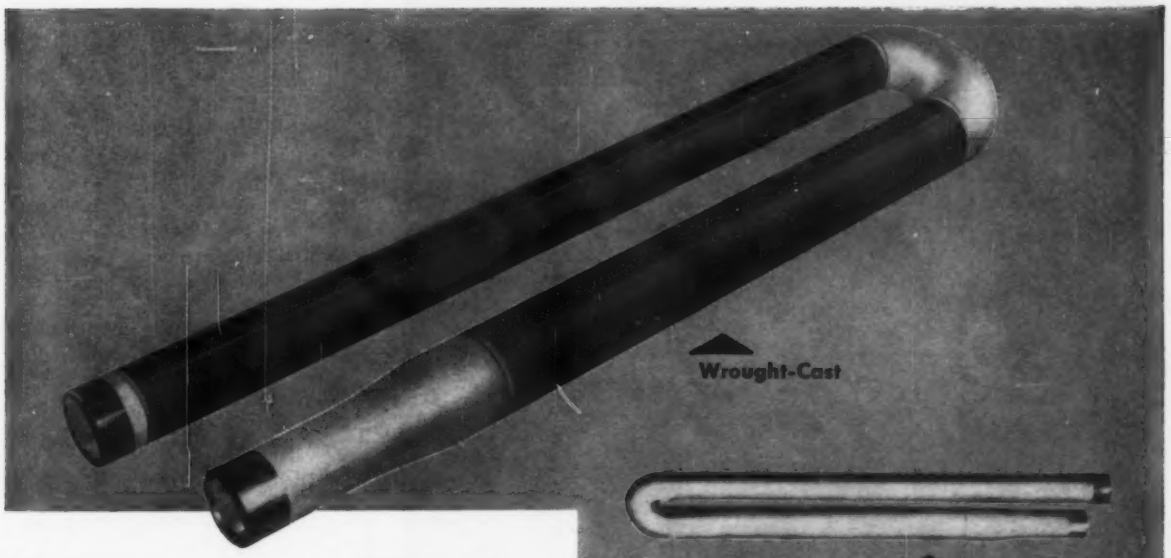
Lawrence K. Welch – now ammonia sales representative in the New England area for the Armour Industrial Chemical Co., Chicago, with headquarters in Brockton, Mass.

J. M. O'Brien – from head of sales to executive vice-president for Metasurf Corp., Detroit.

Ottilie M. Amminger – from chief metallurgist, H. K. Porter Co., Inc., St. Louis, to the University of South Carolina faculty as associate professor of mechanical engineering.

Joseph W. Duba – from assistant manager to manager of the Cincinnati sales branch of Crucible Steel Co. of America, Pittsburgh.

Hamilton Migel – from vice-president in charge of engineering and research to vice-president for planning new products and product development for Magnaflux Corp. in Chicago.



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Unique General Alloys'

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give consistent long life

General Alloys' combination *Wrought-Cast* Radiant Tube Assemblies give consistent long life because they combine a *cast* return bend with straight tubes made from *rolled and welded plate.*

This design utilizes the erosion resistance of the casting where it is most needed . . . at the return bend. The uniform wall section of the plate forming the straight tube, and its smooth interior surface, prevent "hot spots" and "carbon build-up" that are the prime causes of erratic tube life.

General Alloys Company is unique as a major producer of *both* castings and fabrications and therefore can recommend, without bias, the type of construction best suited for your needs.

For complete data, quotes, or engineering service contact the office nearest you . . . or write General Alloys Company, 401 West First Street, Boston 27, Massachusetts.

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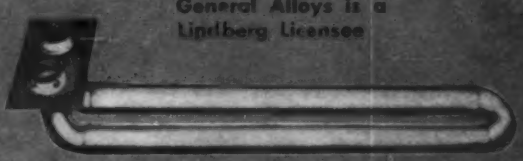

All Fabricated

General Alloys Company also produces entirely cast, as well as entirely fabricated radiant tube assemblies, in all the heat resisting alloys for every purpose and in every size.

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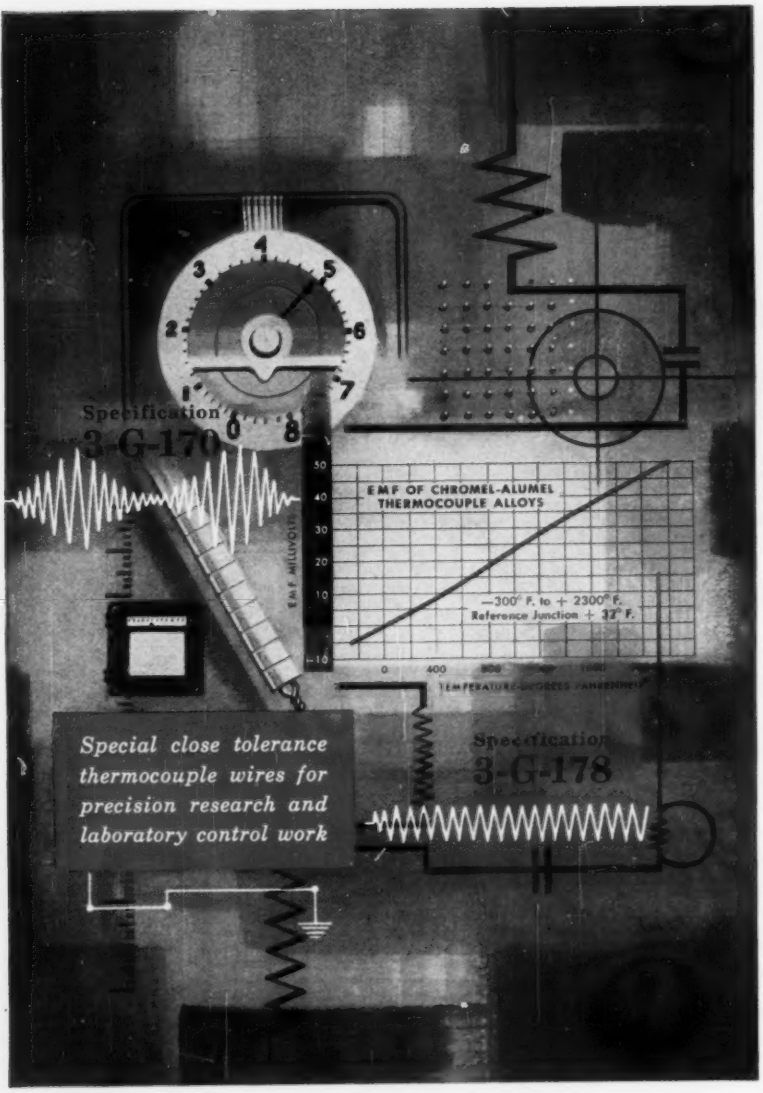
Sharpsburg, Pa.

ST. LOUIS 16, Missouri
Associated Steel Mills, Inc.
P.O. Box 1986, Meramec Station

Circle 2383 on Page 48-B



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Hoskins Chromel-Alumel thermocouple alloys are the world's basic standard of accuracy for controlling the heat treatment of metals—the *only* base metal materials known having established and guaranteed temperature-emf characteristics over a useful operating range from −300° F. for cryogenic applications up to 2300° F. for measuring temperatures in industrial furnaces, nuclear reactors and jet aircraft engines.

Now, in addition to standard guaranteed millivoltage material, these extremely durable, ultra reliable alloys are also being produced in the following special grades for precision quality control:

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Available through instrument manufacturers, thermocouple fabricators, and pyrometer service companies. Write for complete technical data.

* *Trade names you can trust for accurate temperature measurement!*

Genuine Chromel and Alumel are produced exclusively by

HOSKINS MANUFACTURING CO.

4441 Lawton Avenue • Detroit 8, Michigan

Custom-Quality resistance, resistor and thermo-electric alloys since 1908

Circle 2384 on Page 48-B

Personals . . .

Nathaniel Crow Fick – from engineering member of a banking and industrial development team, serving as consultant to the Government of the Sudan, to chief of the technical services and special projects division, Office for Private Enterprise, International Cooperation Administration, Washington, D. C.

Roy K. Cannon – from western district sales manager to sales manager of the Electro-Alloys Div., American Brake Shoe Co., Elyria, Ohio.

George C. Floyd – from vice-president to senior vice-president, for Vanadium Corp. of America in New York.

Peter Petroff – transferred to the home office of Heatbath Corp., Springfield, Mass., as eastern district sales supervisor.

R. P. Stuntz – from assistant sales manager to manager of field sales, refractories division, Babcock & Wilcox Co., New York.

Albert J. Smith – from sales manager of the electrode division to vice-president in charge of electrode division sales of the McKay Co., Pittsburgh.

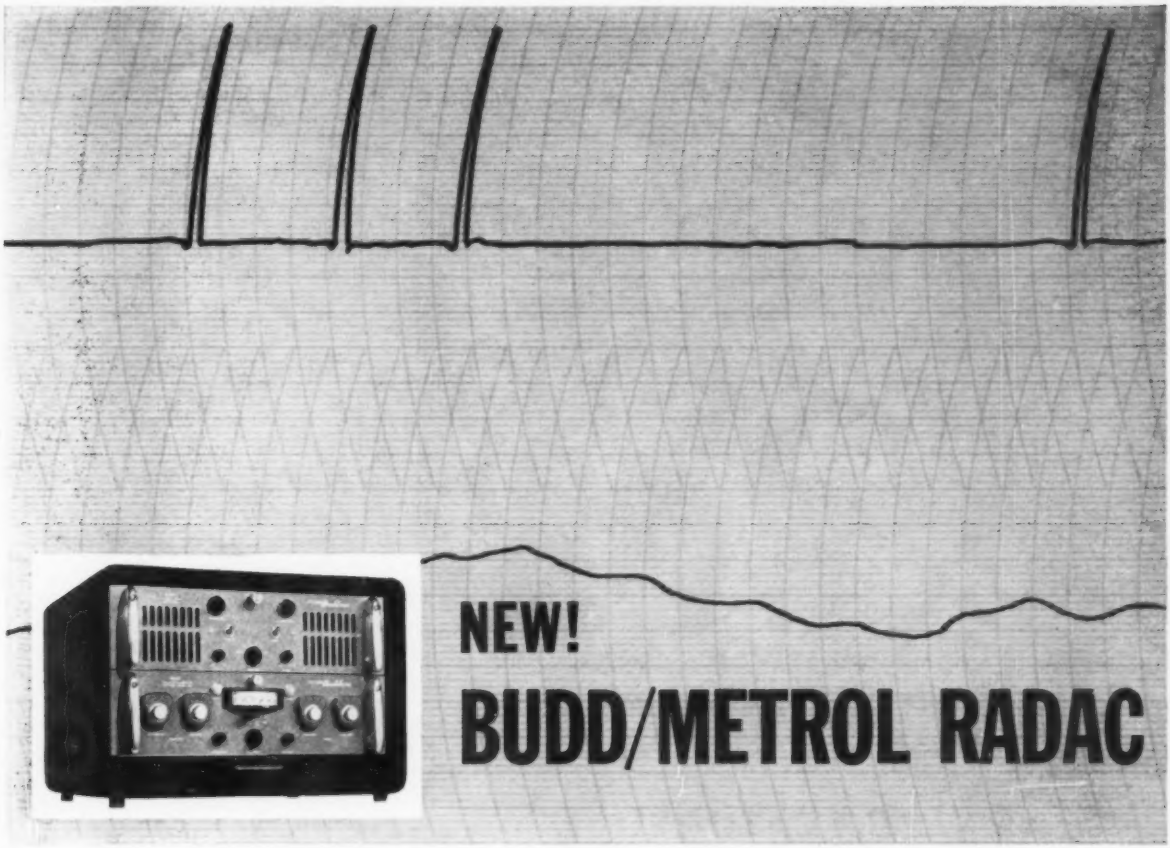
Martin Kurz – from project engineer to manager of porous metals, Pall Corp., Glen Cove, N.Y.

Herbert T. Florence – elected president and general manager, Cleveland Crane & Engineering Co., Wickliffe, Ohio.

Andrew R. Walsh – from the mill metallurgy department to assistant metallurgist, high-temperature alloys, for Carpenter Steel Co., Reading, Pa. **Charles A. Divine, Jr.**, formerly on Carpenter's technical service department staff and stainless steel research and development staff, is assistant metallurgist, stainless steels.

J. M. Courier – now assistant sales manager for the chemical processing division, Detrex Chemical Industries, Inc., Detroit.

G. William Bauer – joined Stauffer-Temescal Co., Richmond, Calif., as sales engineer.



NEW!
BUDD/METROL RADAC

. . . multiple-frequency eddy current inspection unit

The Budd/Metrol RADAC Model 302 . . . latest addition to Budd's expanding line of specialized equipment for quality control . . . is a two-channel electromagnetic instrument that brings new versatility, sensitivity, selectivity and speed to the nondestructive testing of metals and metal products. Combining the principles of Fourier analysis and phase analysis for the first time, the RADAC's flaw detection channel ignores internal stresses, dimensional variations and variations in physical properties . . . is sensitive almost exclusively to discontinuities. Its second, or absolute channel, complementing the first channel, is selectively sensitive to such variables as diameter, wall thickness, eccentricity, coating and plating thickness and physical properties.

Simultaneous two-channel operation is obtained from a single sensing head, and both outputs can be recorded at the same time with a dual channel oscillograph recorder. Focused field test coil sensing heads . . . another exclusive RADAC feature . . . increase the information content of the test signal by properly shaping the electromagnetic field, providing exceptional sensitivity and ability to resolve variables.

The wide choice of test frequencies available with the RADAC covers the range from 1 kilocycle to 4 megacycles. Test coils include OD, ID, area probe and microprobe types. Frequency change boards and test coils are supplied as plug-in units for fast changing, making the RADAC a highly flexible tool for both surface and deep inspection of flat stock, bar stock, tubing and varied other shapes. Punched card programming is available on single-channel RADAC Model 440, enabling RADAC inspection to be applied under production line conditions by semi-skilled personnel. **For detailed description, write for Bulletin IM-1000.**

Other outstanding test equipment from Budd/Metrol: Model 810 Electromagnetic THICKNESS GAGE . . . Model 910 HEATCHECK for alloy identification . . . both fully transistorized and portable. Ask for Bulletins IM-1001 and 1002.

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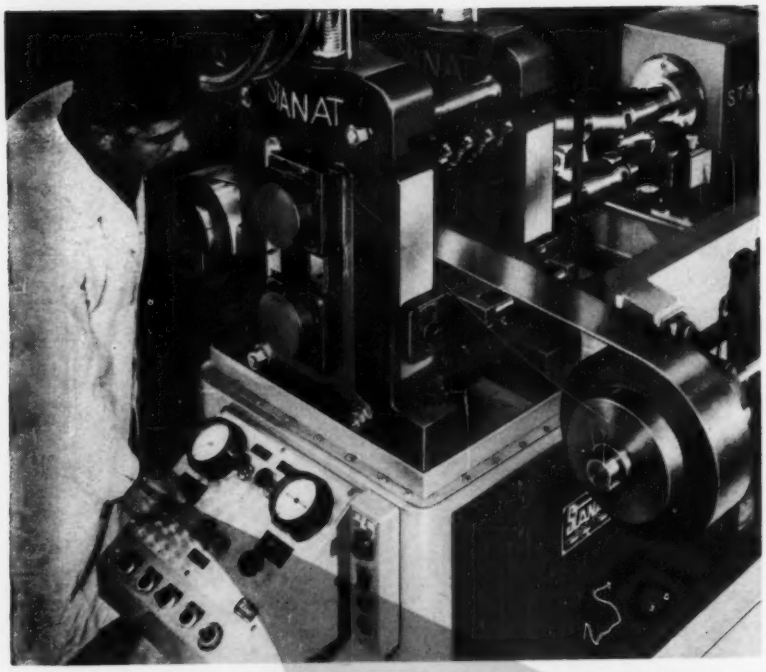
In Canada: Budd Instruments, Ltd., 170 Donway West, Don Mills, Ont.

Circle 2385 on Page 48-B



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Developed especially to meet the demand for a low cost, high precision rolling mill for use in laboratories and pilot production plants, these new Stanat mills are availabie with a complete line of accessories which can be furnished with the mill, or added later. Even the reversing mill feature can be added at a later date.

■ Stanat builds a complete line of laboratory and production rolling mills in a variety of sizes. Find out more about these economical rolling mills today.

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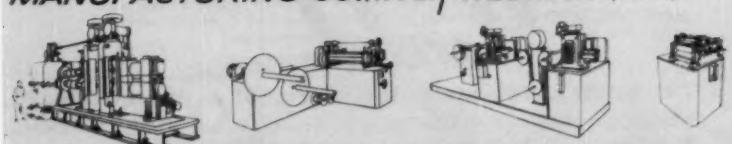


MFR'S OF ROLLING MILLS, GANG SLITTERS, WIRE FLATTENING MILLS, ROLLER LEVELERS AND BULL BLOCKS

Circle 2386 on Page 48-B

Personals . . .

Kenneth Metcalfe – from chief metallurgist of Universal-Cyclops Steel Corp.'s Bridgeville, Pa., plant, to manager of technical service. At the same time **A. Nagy**, formerly research associate, and **T. A. Felk**, formerly in the Bridgeville metallurgical laboratory, were named metallurgical engineers, technical service.

Eugene R. Grieshaber – now senior field engineer, located in Milwaukee, Wis., for Metals & Control Div. of Texas Instruments Div. He was formerly with the company's west coast territory.

Benjamin Litt – from assistant to the director of engineering, Sylvania-Corning Nuclear Corp., Bayside, N. Y., to assistant to the vice-president of research and development of the newly formed Semiconductor Div. of the General Instrument Corp. in Hicksville, L. I., N. Y. Until its merger in August, the Semiconductor Div. was known as the General Transistor Corp., located in Jamaica, N. Y.

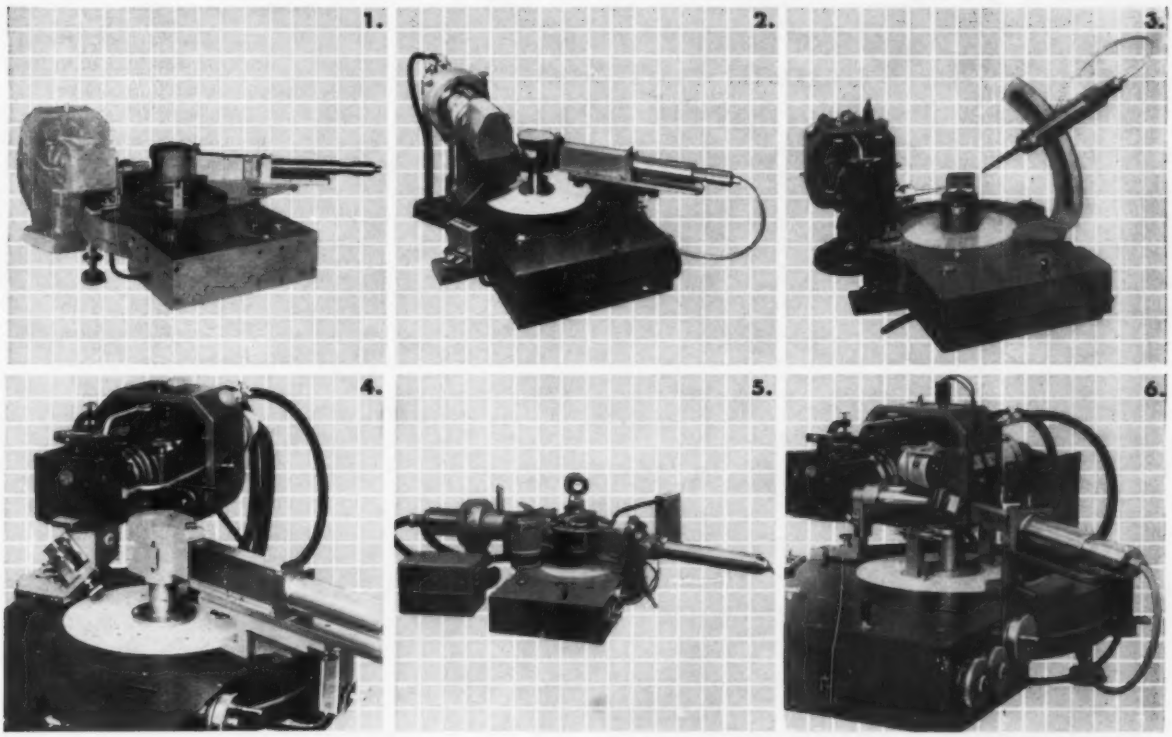
William F. Gilligan, Jr. – from sales engineer covering the Long Island territory for Whitehead Metals, Inc., to sales manager of the New York branch.

Robert S. Thompson, president, H. P. Deuscher Co., Hamilton, Ohio – elected president of the Ductile Iron Society, Cleveland. At the same time **William Beatty**, vice-president, Morris Brean & Co., Cedarville, Ohio, was elected vice-president. Elected to the Society's Board of Directors were **Sam F. Carter** of American Cast Iron Pipe Co., Birmingham, Ala. and **B. L. Baptist** of the Beloit (Wis.) Iron Works. **James H. Lansing** is executive secretary of the organization.

Walter C. Hahn, Jr. – recent recipient of a Ph.D. degree from Pennsylvania State University, now assistant professor of metallurgy at the Montana School of Mines.

John S. Roberts – from metallurgist, American Manganese Bronze Co., Philadelphia, to assistant superintendent in the Foundry and Propeller Shop of Bethlehem Steel Co. at Staten Island, N. Y.

X-RAY DIFFRACTION AND SPECTROSCOPY



1. Counter Tube Diffractometry. 2. Spectroscopy. 3. Single Crystal Studies. 4. Spectroscopy of Small Areas. 5. Vacuum Spectroscopy of Light and Heavy Elements. 6. Studies of Orientation.

VERSATILITY!

RCA's horizontal goniometer performs 6 functions

Unusual versatility is an important distinguishing characteristic of RCA's X-Ray Diffraction and Spectroscopy Equipment. This versatility is graphically demonstrated by the horizontal goniometer which can perform six different functions merely by adding accessories, as illustrated above.

RCA X-Ray Diffraction and Spectroscopy Equipment offers many other outstanding features which make it one of today's most specified lines. For example, the DC regulated and filtered power supply; the option of mounting two tube stands on the Crystalloflex IV; a kit which permits conversion from diffraction to spectroscopy in minutes; and the new vacuum spectrometer for analysis of light and heavy elements. For those engaged in film studies of all kinds, the RCA Table Model Crystalloflex II can be bought, complete with cameras, for as little as $4000.

A NEW LEASING PLAN now makes it possible to obtain all RCA scientific instruments, including the Electron Microscope, with no down payment, low monthly terms, and a favorable option to buy.

For complete information write to RCA, Dept. O-72, Bldg. 15-1, Camden, N.J.

Crystalloflex IV and Electronic Circuit Panel with Diffractometer and Guinier Camera mounted on the generator.

RCA

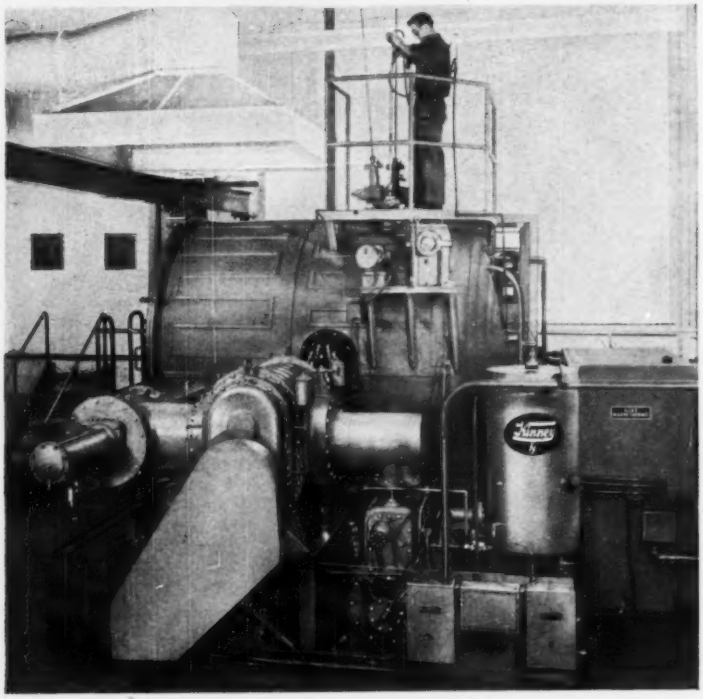
The Most Trusted Name in Electronics

RADIO CORPORATION OF AMERICA

Circle 2387 on Page 48-8

Kinney®

Builds the Vacuum Furnaces to Produce PURE Metals BETTER!



Above, you see a highly versatile KINNEY Vacuum Furnace now in operation at the Watertown Arsenal, Watertown, Mass. In addition to its primary function of Melting and Casting high purity metals, it may be used for degassing atomic materials, sintering carbon molds and alloying reactive metals.

It handles loads up to 1000 lbs. of steel (2200 lbs. uranium) with provision to pour in increments at automatically controlled pouring stations, or pour a full load in 60 seconds. Two interchangeable melting coils, for full capacity and half capacity loads, each provide temperatures up to 3400°F. The pumping system can evacuate the 8' diameter x 11' chamber from atmosphere to 5 microns in 7 minutes and can attain ultimate pressure in the order of .5 micron.

This Furnace is one of a large family of KINNEY designed Furnaces available for Vacuum Melting, Alloying, Refining, Sintering, Heat Treating, Annealing, Welding and Brazing. Details of function, construction and operation may be had by consulting a KINNEY High Vacuum Furnace specialist. Write today!

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Furnaces ☐ Pumps ☐ Vacuum Gages ☐

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Circle 2388 on Page 48-B

Personals . . .

Auvo Kemppinen – transferred from the Phoenix (Ariz.) Extrusion Plant of Reynolds Metals Co. to the metallurgical research laboratory in Richmond, Va., working on plastic deformation of metals.

Pierre P. Turillon – now supervisor of the mill and foundry section at International Nickel Co.'s Research Laboratory in Bayonne, N. J.

R. R. Ruppender – from advance manufacturing engineer in the Flight Propulsion Div. of General Electric Co., Cincinnati, Ohio, to head of research and development, Ferrotherm Co., Cleveland.

Ronald L. Pollard – now quality control engineer for Ormet Corp., Hannibal, Ohio.

John A. Wiseman – now chief engineer of the eastern operation of the Canning Div., Food Machinery and Chemical Corp.

Emerson H. Wright – from research metallurgist, Alcoa Research Laboratories, to vice-president in charge of laboratories, Aluminum Inc., and director of laboratories, Metallurgical Inspection & Testing Co., Fort Lauderdale, Fla.

Allan J. Rosenberg – now chief of quality control in charge of plating solution analysis laboratory and all plating processes for Simmons Plating Works, Inc., Atlanta, Ga.

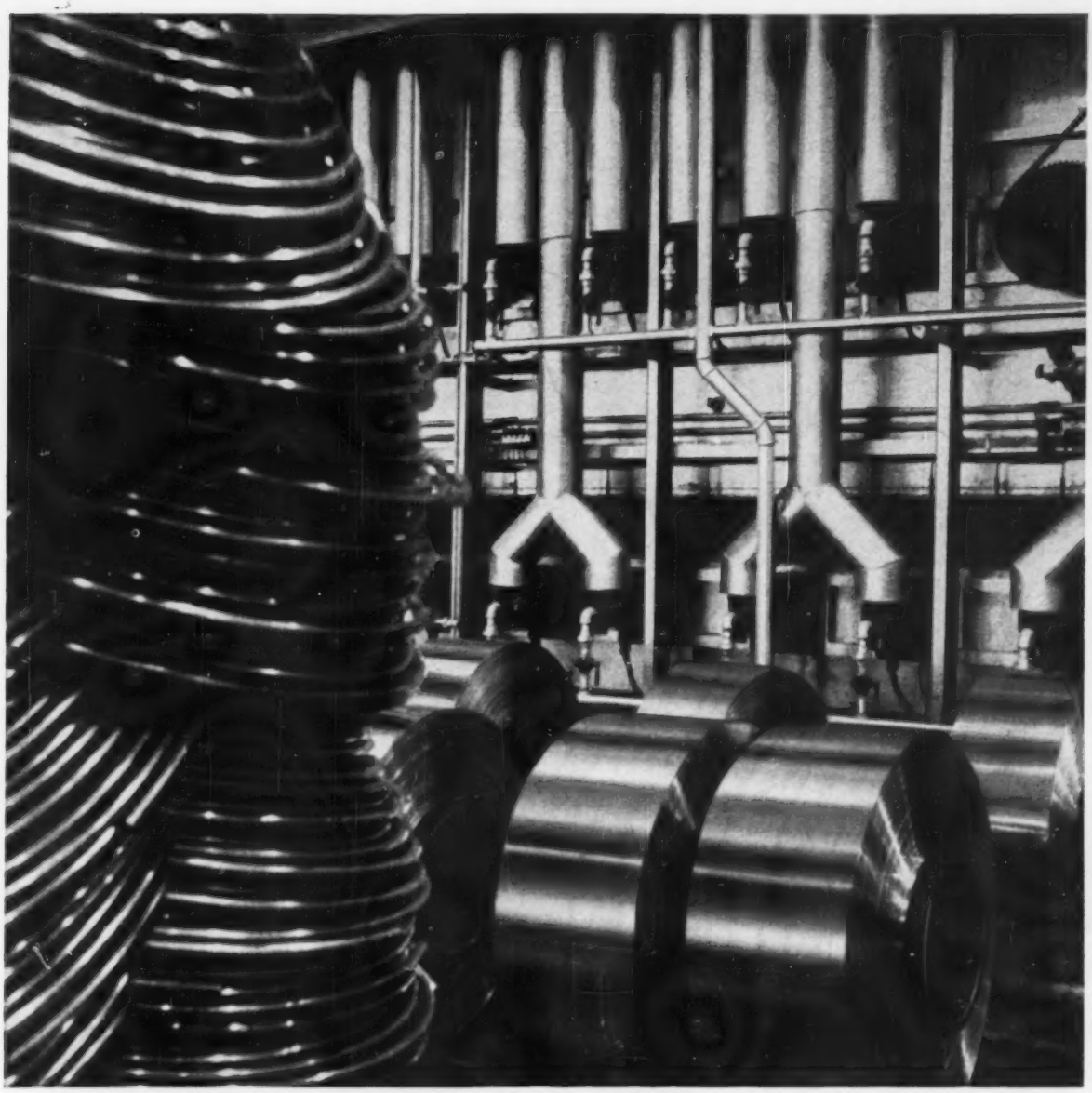
Fred Domina – from senior scientist, research laboratory, Lockheed Missile & Space Div., Palo Alto, Calif., to sales manager, Armetco, Inc., Wooster, Ohio.

J. B. Kopec – now director of research and metallurgy, Keystone Steel and Wire Co., Peoria, Ill.

Malcolm Adler – now manager of the new Cleveland office for Hull Corp., Hatboro, Pa.

Mark G. Morris – from chief of the materials control laboratory, Kamon Aircraft Corp., Mossup, Conn., to chief metallurgist, White Motor Co., Cleveland.

Richard A. Papa – from Westinghouse Electric Co., Springfield, Mass., to Boeing Airplane Co., Seattle, Wash.

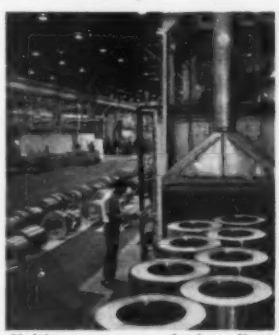


American Brass relies on GAS for precise control in heat processing

Five huge gas-fired furnaces handle heat processing at the new American Brass Company plant near Los Angeles—largest copper and brass mill in the West.

Gas heat anneals their copper and brass coils, tubing and strip . . . processes copper billets for extrusion and for piercing . . . and bright-finish anneals copper coils and tubing.

Why the choice of gas heat? Precise temperature control! Gas heat develops the required temperatures rapidly. Maintains them precisely. Adapts most easily to automatic temperature control. Offers unbeatable fuel economy.



Multi-purpose, gas-fired, radiant tube, forced circulation roller hearth furnace at American Brass Company's new Los Angeles mill. Used in the bright finish annealing of copper coils, tubing and strip.

American Brass, and thousands of other companies, can tell you *gas* is technically right and economically sound for all types of heat processing. Call the Industrial Sales Engineer at your local gas company. *American Gas Association.*

FOR HEAT PROCESSING GAS IS GOOD BUSINESS!

Circle 2389 on Page 48-B

Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

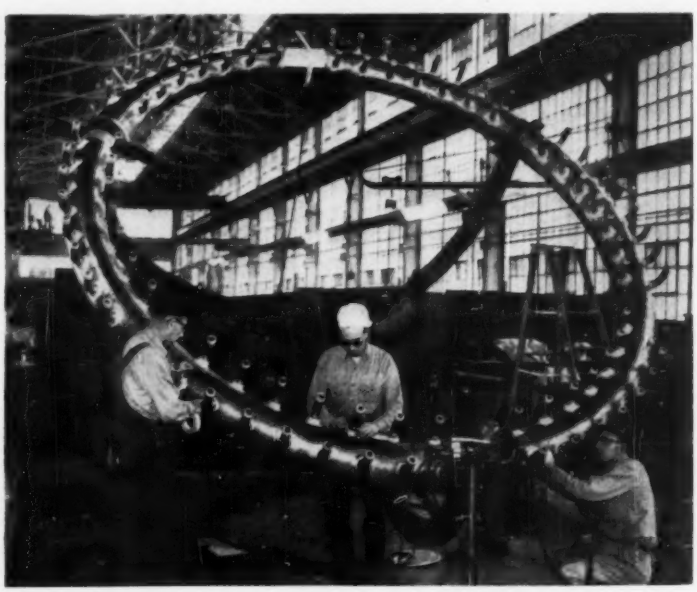
Nondestructive Testing of Reactor Materials

Digest of a report of the Symposium on Nondestructive Testing Trends in the A.E.C. Reactor Program, held in Germantown, Md., May 20, 1960.

THE NEED AND DEMAND for high standards of integrity in nuclear reactor components, especially fuel elements, has resulted in a continuing program within the Atomic Energy Commission for the development of nondestructive testing methods and techniques. In line with this, A.E.C. sponsored a meeting which was designed to *(a)* acquaint industry with recent developments in nondestructive testing within the A.E.C.; *(b)* acquaint equipment manufacturers and suppliers of testing services with the nondestructive testing problems faced by the A.E.C.; *(c)* indicate the present trends in nondestructive testing within the A.E.C.; and *(d)* indicate some of the expected developments and problems in reactors, fuel manufacturing and fuel recovery plants. In summary, the A.E.C. wanted to review nondestructive testing and give an idea of the problems which must be solved in the days ahead.

In the introduction, the technical chairman discussed the problem of specifications in the nuclear reactor field. Since the technology for design, construction, and operation of reactors is still developing, most of the nuclear reactors that have been built to date are each based on different approaches. As a consequence, specifications for reactor materials have been quite stiff. This seems reasonable when the integrity of material and system is so important. Rigid specifications are undoubtedly justified for new materials and new methods of fabrication where the effects of mechanical flaws, inhomogeneities and impurities are not known. To elaborate, if there is ever a time for stringent design requirements, it is in the initial program and initial experiments. There is no magic by which reliability can be obtained. There are no tricks, no cheap way, no easy road. Reliability is an engineering problem which requires information on material and a thoroughly coordinated engineering effort to produce a proper and safe

Fig. 1 — Outlet Header for Plutonium Test Reactor at Hanford. Built by Dravo Corp., this header consists of three sections of Type 304 stainless. A complicated assembly such as this must be thoroughly tested before installation



No. 3 Coil Preparation Line At Wheeling Steel Corporation's Yorkville Plant

Wean, Wheeling and Coil Preparation . . .

Inspecting and side trimming coils at high speeds, this Wean coil preparation line at Wheeling Steel Corporation represents another advance in the development of high speed processing lines. This new Wean line is designed to produce oiled black plate, or to prepare coils of various gauges for tinning and galvanizing. Capable of handling coil weights up to 42,000 pounds, the No. 3 Yorkville line can side-trim strip up to 45 inches in width and from .006 to .0359 in thickness.

Other new features of the Yorkville line are a butt-type shear-welder that produces a very smooth joint, minimizing distortion in the wraps of built-up coils; and a non-contact thickness gauge with indicating and recording instruments.

Wean's "creative engineering" has developed modern coil preparation lines that offer speeds of over 4,000 fpm, increased efficiency and higher prime product yield in subsequent coating operations. Wean experience in this field can be a valuable asset if coil preparation lines are part of your production planning.

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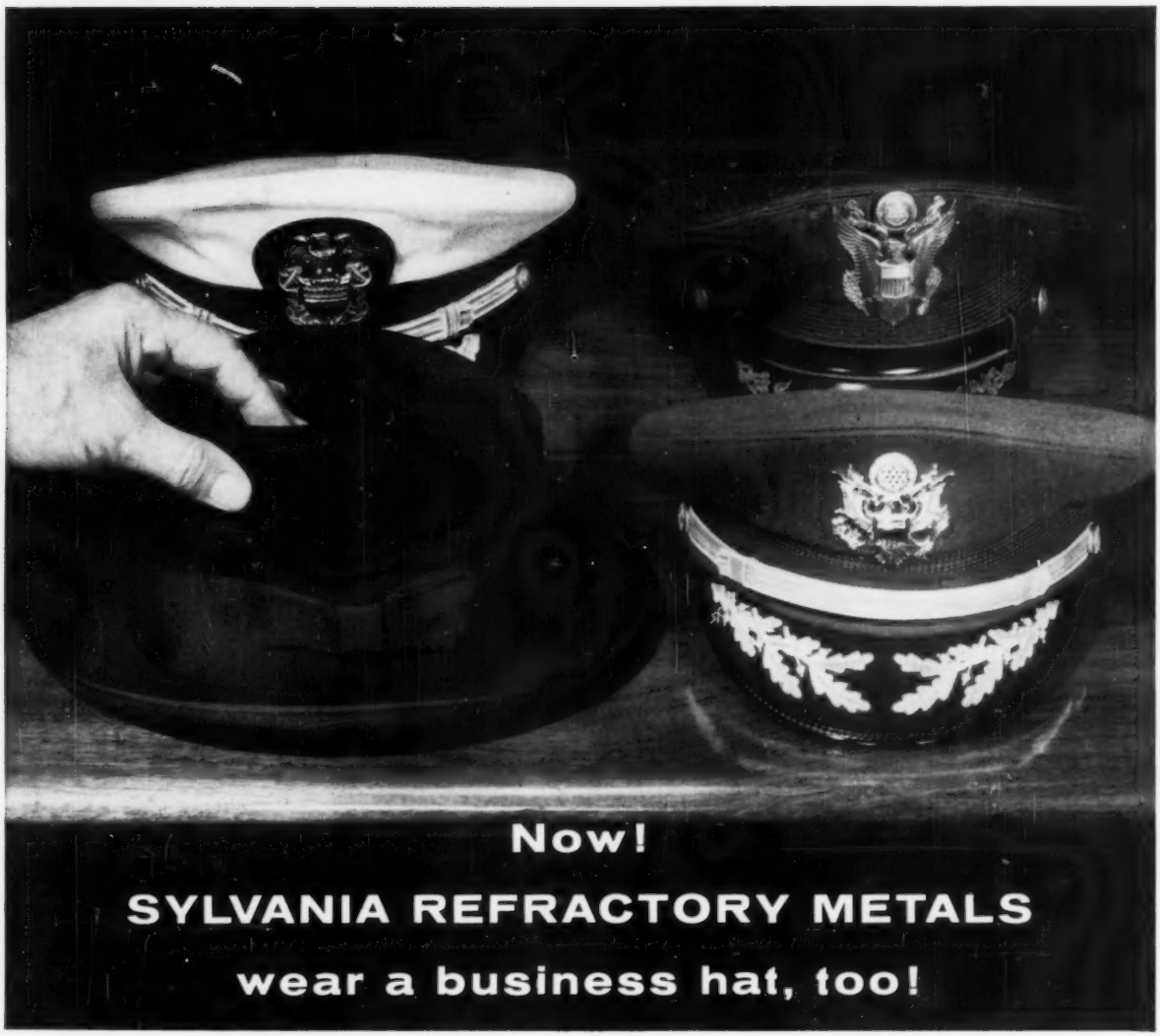

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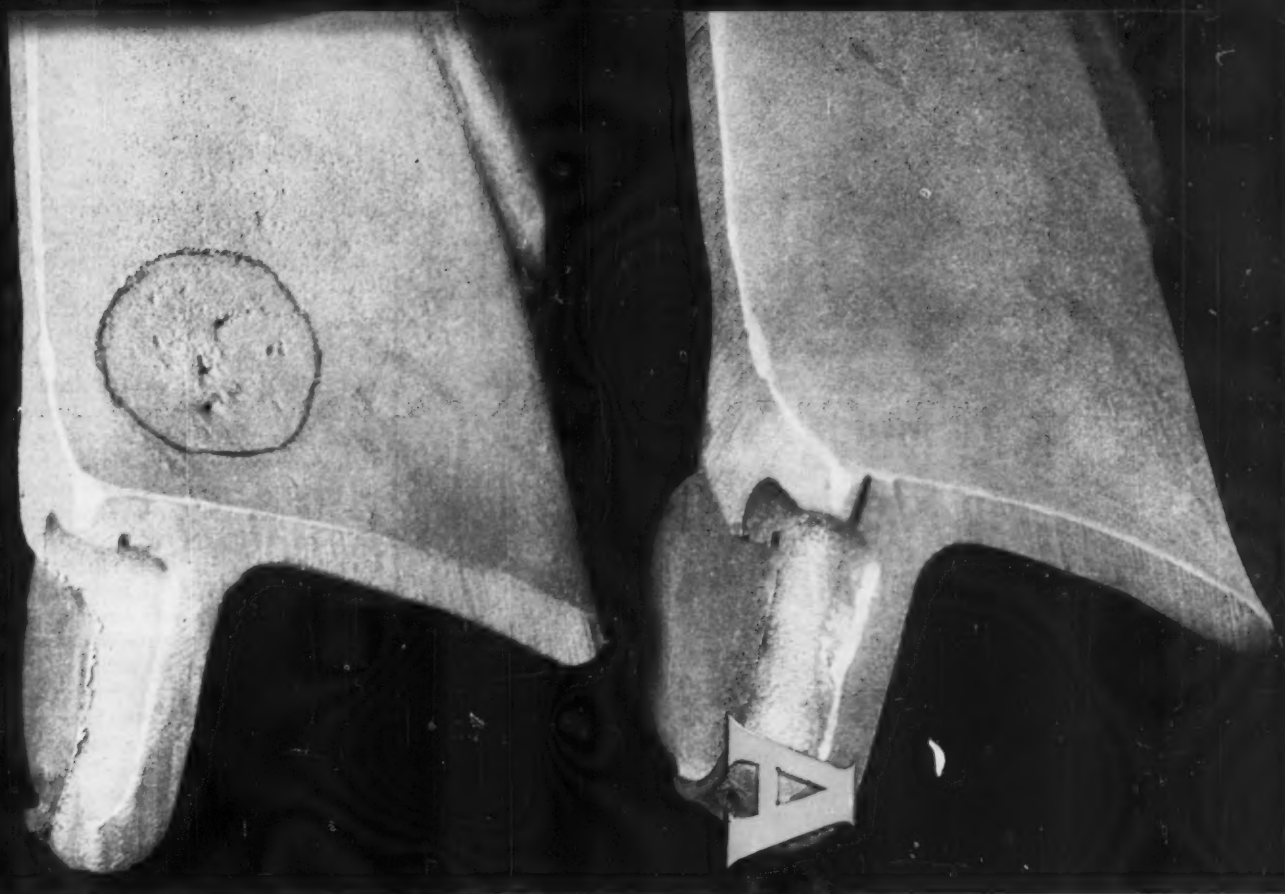
Circle 2390 on Page 48-B



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Comparative photograph illustrates the effect of PT treatment. Casting on left from standard aluminum alloy, shows typical shrinkage over a large area. Compare with casting on right, cast in PT grade, under the same conditions! Alloy: F460 (319)

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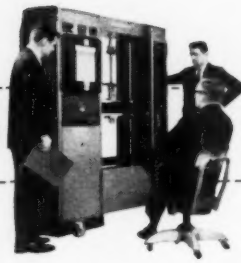

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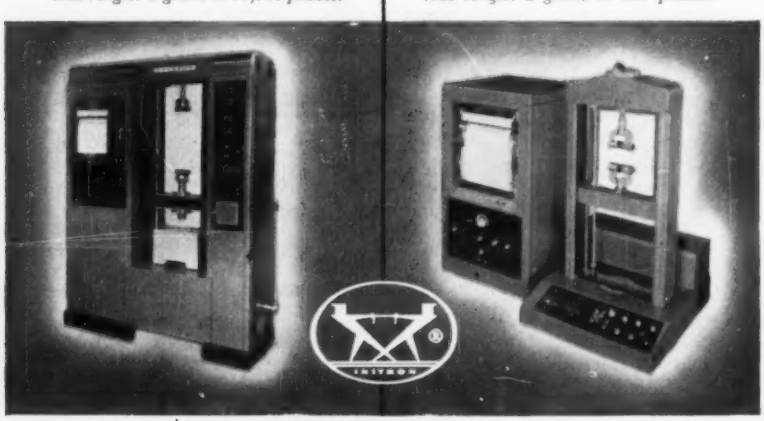

Circle 2392 on Page 48-B

Nondestructive . . .

design. This must be followed by production and inspection techniques having the highest possible order of perfection.

Testing With Radiation

G. M. Taylor of Los Alamos Scientific Laboratory, in reviewing applications of radiation, covered conventional radiography, autoradiography, microradiography, fluoroscopy, radiation gaging, X-ray fluorescence analysis, electron radiography, gamma radiation counting, gamma radiation spectrometry, electron microscopy.

Taking each in order, conventional radiographic techniques have been used extensively to determine the structural soundness of welds, tubing, pressure vessels, and other parts, some of which are quite unusual (hafnium control rods, zirconium-to-hafnium butt welds, and Zircaloy welds, for instance). Uranium, of course, has been radiographed in a number of geometrical forms. Radiography is also useful in examining reactor fuel elements for uniformity of loading.

Autoradiography has been used for measuring the thickness of nickel coatings on plutonium and uranium, and steel and Zircaloy coatings on uranium. Microradiography has been used to obtain information about mixtures of materials such as uranium in graphite. Radiation gages (using either a radioactive material or an X-ray generator) are widely used. The X-ray fluorescence technique has been used for the quantitative analysis of uranium or plutonium in solution, or uranium in ores, and of uranium or plutonium in aluminum. It has also been used to determine the thickness of aluminum cladding on plutonium. Electron radiography has been applied to materials where an element of high atomic number is distributed in a matrix of low atomic number (such as uranium graphite), and to aid in studying and identifying inclusions under similar circumstances. Electron microscopy has been useful in studying the crystal structure of materials for fuel elements, particle size determinations, coating studies, and in the study of heat transfer and structural materials.

Gamma counting has been used to measure the uniformity of ura-

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Circle 2394 on Page 48-B

Nondestructive . . .

nium-235 distribution in fuel elements, to assay fuel elements and to insure proper identification of high and low-zone loaded fuel plates. In gamma spectroscopy the intensity of specific gamma radiation energies are measured. This method has been used to determine the degree of uranium-235 enrichment, to measure the uniformity of reactor fuel element loading, to assay uranium ores, and to assay solutions of plutonium-239 and uranium-235.

Testing With Ultrasonics

Robert McClung of Oak Ridge National Laboratory, in reviewing the use of ultrasonics in the A.E.C. nuclear reactor program, stated that ultrasonics are used for *(a)* grading surface quality of uranium fuel cores; *(b)* inspecting uranium rods (0.316 and 0.433 in. in diameter) for internal flaws greater than 1/32 in. in any direction; *(c)* determining elastic constants of various materials; *(d)* measuring sound velocity to determine if uranium has been beta heat treated; and *(e)* determining ultrasonic attenuation. The latter use provides information concerning the grain size and other variations in metallurgical structure.

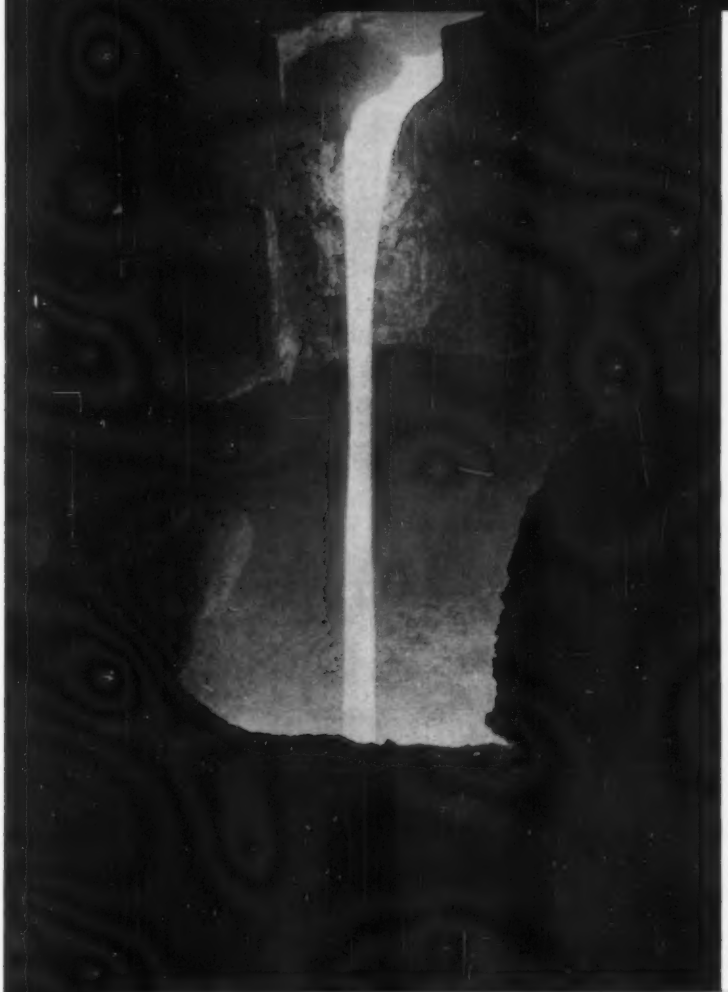
One of the major uses of ultrasonics has been in detecting and evaluating nonbond in plate-type and cylindrical fuel elements. In very general terms, there are two types of plate elements, both of which are amenable to the through-transmission technique. One has the cladding bonded directly to the fuel core; the other has a ribbed structure (similar to the aircraft honeycomb structure) with the fuel being placed in the void areas. A number of installations have equipment which automatically scans the entire plate fuel element, recording bonded and nonbonded areas.

It is frequently necessary to exercise close control of the thickness of various parts, particularly in thin sections. One such application is the continuous measurement of wall thickness variations of tubing for heat exchangers, fuel capsules, or other applications.

Other Test Methods

A staff member of Los Alamos Scientific Laboratory, P. D. Edwards,

In iron foundries today the trend is to...



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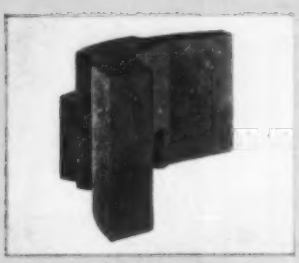

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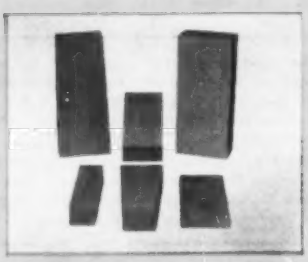
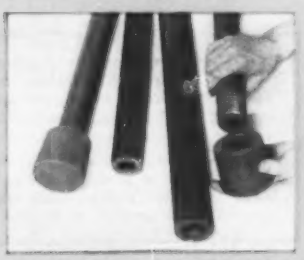


CARBON BRICK AND PASTE—Proved materials for cupolas and runout troughs.



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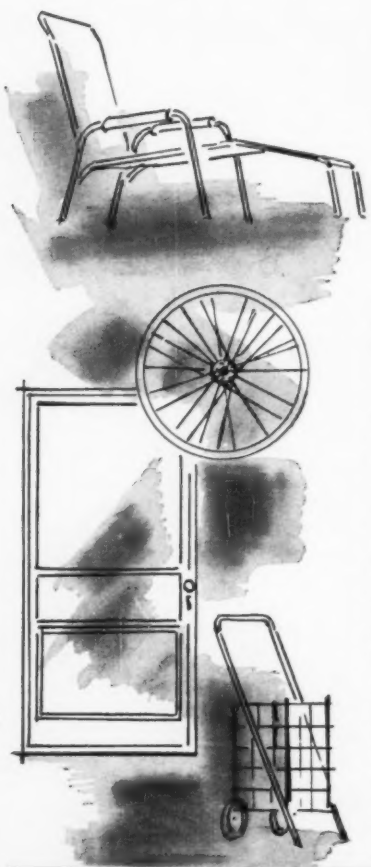

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ON ZINC—Iridite plus Irilac gives longer product life, brighter appearance. Color range—clear Iridite to olive drab, plus colored dyes.

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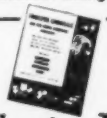

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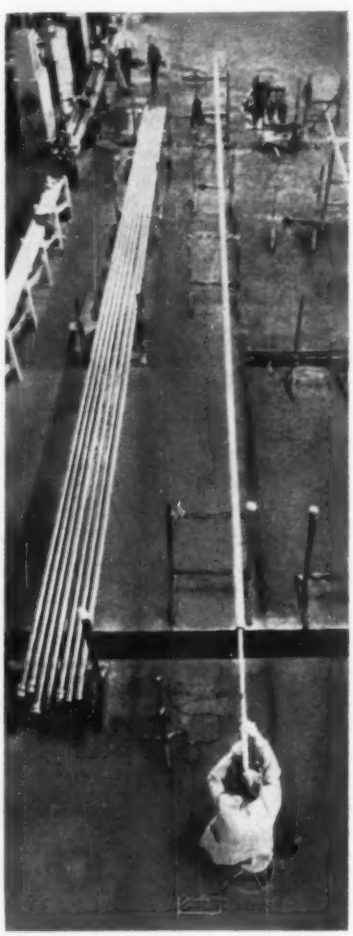
Circle 2396 on Page 48-B

Nondestructive . . .

reviewed leak, thermal and surface test methods, all of which are vitally important in the field of nuclear energy. In a reactor installation, for example, the leakage of radioactive gases or liquids or the mixing of highly reactive materials such as sodium and water are such serious matters that the most extensive preventive methods must be employed.

Leak tests include hydrostatic tests for pressure vessels, halogen leak detectors, helium leak, and radioactive tracers, both liquid and gas. Thermal testing methods involve thermal detecting devices such as thermometers, thermocouples, bolometers, thermosensitive phosphors,

Fig. 2 – Zircaloy-2 Tubes (Extruded by Allegheny Ludlum) Being Examined for Internal Finish After Sizing to Final Dimensions. Comprehensive testing also includes hydrostatic, dimensional and chemical tests



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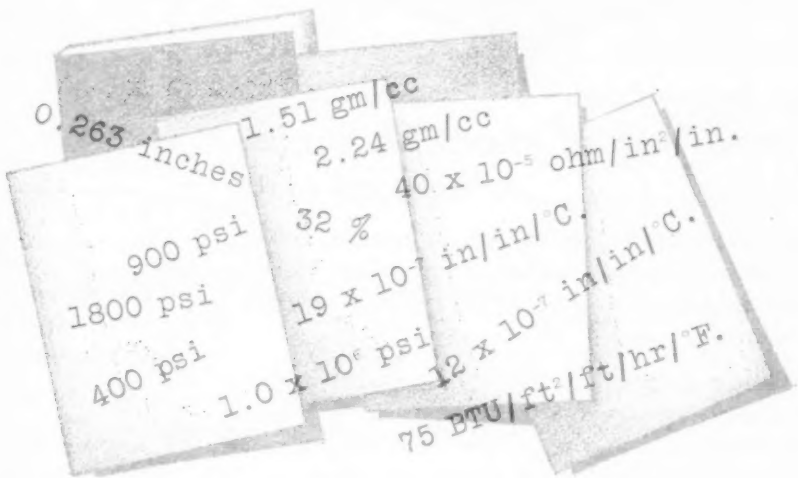

Among the typical physical properties detailed for electrodes in various grades and sizes are maximum particle size... apparent and real density... porosity... resistivity... rupture... compressive and tensile strength... elasticity... thermal expansion and conductivity.

Typical chemical properties of the electrode grades show percentages of ash, sulfur, silicon, iron, calcium, aluminum, vanadium and other impurities.

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Circle 2397 on Page 48-B

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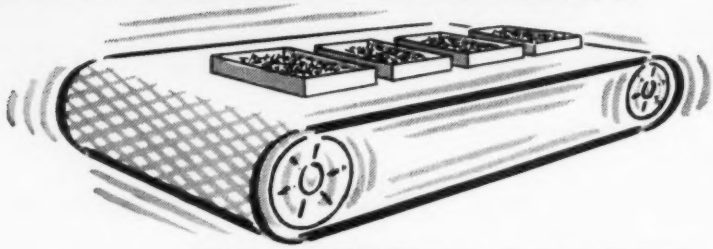
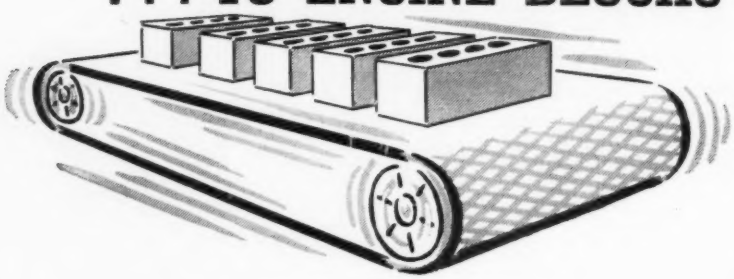


. . . TO ENGINE BLOCKS



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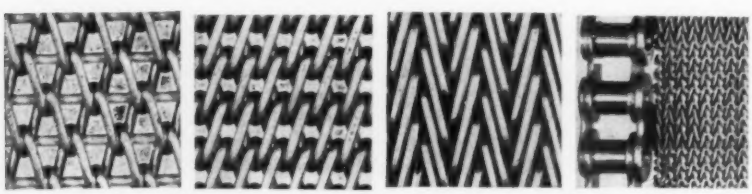
Process temperature and furnace atmosphere are no problem for Ashworth Engineers, they have at their command any metal or alloy that can be drawn into wire . . . they have the experience to specify the mesh or weave that will supply the correct surface characteristic to overcome any problem of circulation or drainage. Ashworth Metal Process Belts have been designed to withstand and operate at temperatures up to 2100°F.

Engineering versatility plus the finest plant facilities in the industry insure quality woven into every Ashworth Belt.



Technical literature is available with no obligation. Write for new High Temperature Catalog.

ASHWORTH BROS., INC.

WINCHESTER, VIRGINIA

Sales Offices in Principal Cities

Circle 2398 on Page 48-B

Nondestructive . . .

infrared sensitive materials, and chemicals.

Visual inspection, one of the simplest inspection methods, often makes use of optical aids such as magnifiers, microscopes and borescopes. Such inspection is also aided indirectly by etching, electrified particle, filtered particle, magnetic particle and penetrant testing.

Because of the relatively heavy use of refractory metals and stainless steels, there seems to be greater dependence placed upon the penetrant tests. There is also a definite move toward a more stringent interpretation of test results. Current specifications attempt to enforce extreme care in the application of these inspections so that all indications of defect must be recorded and must be assumed to be produced by a rejectable defect unless it is proved otherwise.

Other surface test methods include strain-sensitive techniques such as strain gages, brittle coatings or photoelastic coatings, and surface roughness measuring devices. In addition, the problems of detecting minute amounts of radioactive surface contamination or microscopic surface inclusions are ever growing ones.

Electromagnetic Tests

The review paper on electromagnetic testing was prepared by J. D. Ross of Du Pont's Savannah River Laboratory. Eddy current methods were being widely used to inspect tubing for very small defects. Because of the large quantity involved, a reasonable inspection rate must be achieved. Due to the sensitivity of eddy current to small defects, a point probe inspection system is desirable. However, this system is slower than an encircling coil system, and attempts to speed up the inspection usually result in a large amount of noise (from the "lift-off" effect) being generated in the electronic circuits. It is difficult to make a point probe ride smoothly on a tube that is rotating at a rather high speed, and any vibration of the probe produces signals that are similar to the defect signals. To overcome this effect, circuits have been devised to separate the signal into its components. Using such circuits the "lift-off" signal can be separated from the

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

Determining the Depth-Hardness of Alloy Steels

The hardenability of an alloy steel is usually measured by the depth to which the steel will harden under specific conditions of heating and cooling. One of the most conclusive methods of determining depth hardness is the end-quench hardenability test (ASTM A255). In essence, this test is as follows:

A 1-in. round specimen, approximately 4 in. long, is heated uniformly to the proper quenching temperature. The specimen is removed from the furnace and placed in a bracket; then a jet of water at room temperature is played on the bottom face of the specimen without touching the sides. This water jet is kept active until the entire specimen has cooled. Longitudinal flat areas are ground on opposite sides of the piece, and Rockwell C readings are taken at 1/16-in. intervals. The resulting data are plotted on graph paper, with the Rockwell C values as ordinates and distances from the quenched end as abscissae.

Experiments have shown that the points on the hardenability curve approximate the cooling rates at the centers of quenched rounds of various sizes; and that the hardness values at the centers of these rounds will correspond very closely with those shown at points on the end-quench hardenability curve.

In general it may be said that when end-quench curves for different steels approximately coincide, these steels can be treated similarly for equivalent tensile properties in sections of the same size.

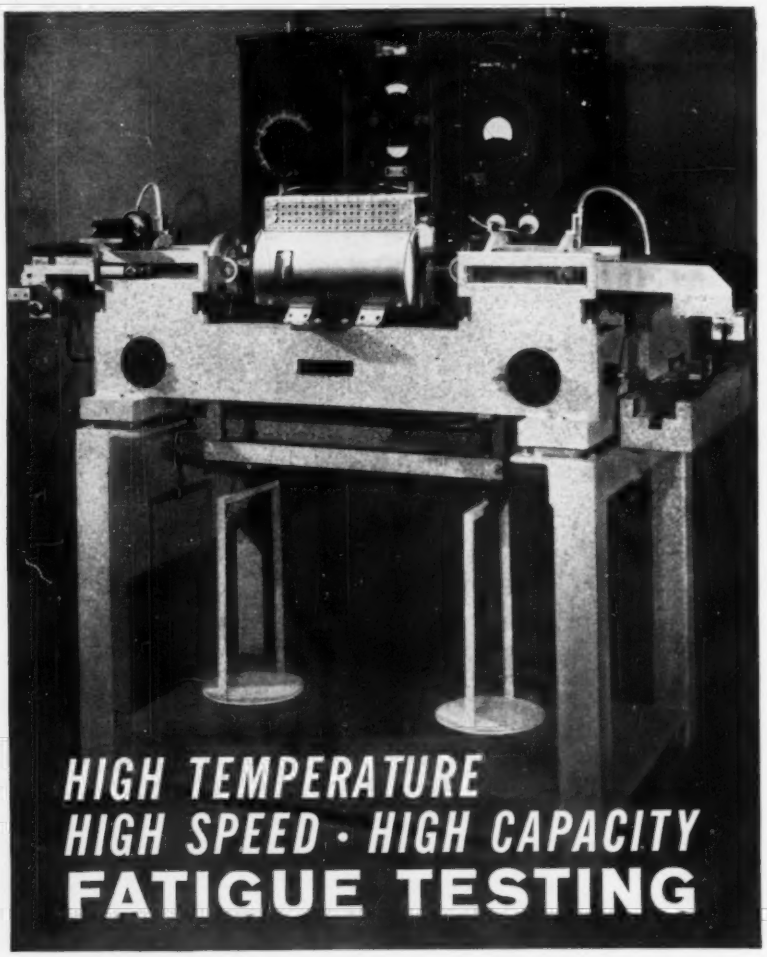
A study of hardenability curves reveals that depth-hardness depends upon the amount of carbon present, the alloy content, and the grain size. Manganese, chromium, and molybdenum are the chief elements that promote depth-hardness, while nickel and silicon help to a lesser degree. It should be noted, also, that phosphorus promotes depth-hardness, while sulphur has a negative effect. In normal low-phosphorus and low-sulphur steels, the two elements neutralize each other.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.
Export Sales: Bethlehem Steel Export Corporation

BETHLEHEM STEEL

Circle 2399 on Page 48-B



with the new 850 in.-lb. Rotating Beam Machine from Budd

Designed for testing new heat-resistant materials used in jet engine, rocket and missile programs, this new Tatnall-Krouse machine provides unsurpassed performance for your most critical applications. It has a bending moment capacity of 850 inch-pounds . . . speeds from 3,000 to 12,000 cycles per minute . . . temperatures from 200 to 1800°F. ±3°. It takes specimens 4 to 8 inches long, and 16 to 20 inches long.

For details, write or call for Bulletin BM-2050.

Other Budd testing equipment includes Tatnall creep testing machines and tensile testing machines, and Tatnall-Krouse variable speed plate machines, constant speed sheet machines, and other rotating beam machines. We will be glad to help you evaluate your testing requirements and select the right equipment.

INSTRUMENTS Budd DIVISION

THE BUDD COMPANY · P.O. Box 245 · Phoenixville, Pa.

Consult your phone book for sales offices in: Atlanta, Ga., Oak Park, Ill., Dallas, Tex., Los Angeles, Calif.
In Canada:
Budd Instruments, Ltd., 170 Donway West, Don Mills, Ont.

Circle 2400 on Page 48-B

Nondestructive . . .

defect signal. Eddy currents are also used to measure plating thickness of nickel on uranium, cladding thickness on plate-type and cylindrical fuel elements, and the measurement of wall thickness of tubing.

It would be very helpful if the manufacturers of nondestructive testing instruments would prepare more and better descriptive literature on what instruments are commercially available and what are the advantages and limitations of each such instrument. Since only three or four basic circuits were used in the various instruments discussed by the speaker, it seems reasonable that the electronic parts could be standardized. Then when an inspection problem arises, only a specially designed probe will be needed.

These instruments should be relatively simple and moderately priced. A simple instrument cannot be made that will cover the frequency range from 60 to 600,000 cycles per sec., but with the present state of the art in etched circuits and plug-in components, it should be possible to provide a basic chassis containing the main power supply and readout circuitry, and to have plug-in strips for various frequencies.

Summary

In addition to its direct value in finding flaws, nondestructive testing is most effective in keeping the quality of materials up to the required level. There is often a tendency to call for a multiplicity of nondestructive tests irrespective of their usefulness, feasibility and cost. Actually, in writing specifications, the nuclear design engineer should be guided by the following two questions:

1. Are the required tests adequate?
2. Are the required tests necessary?

In view of the emphasis on new and improved materials, along with the use of lower factors of safety, higher temperatures and higher power in nuclear reactors, nondestructive testing must give quantitative rather than simply qualitative information. To achieve this goal, much research and development in the technology of nondestructive testing will be required. In brief, not only more but better nondestructive testing must be done.

W. J. McGonnagle

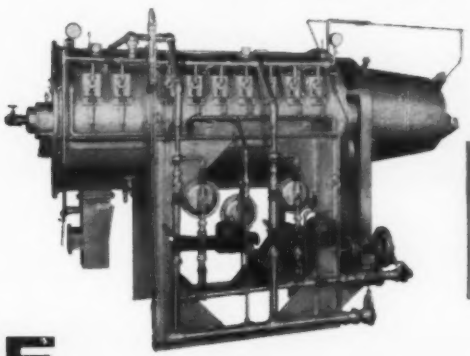
choose the versatile Best...

AGF

AMERICAN GAS FURNACE CO. 82 YEARS OF PIONEERING 1878 1960 ELIZABETH, N. J.

ROTARY RETORT AND RECIPROCATING HEARTH

for all small parts heat treating



AGF

Model 136-60

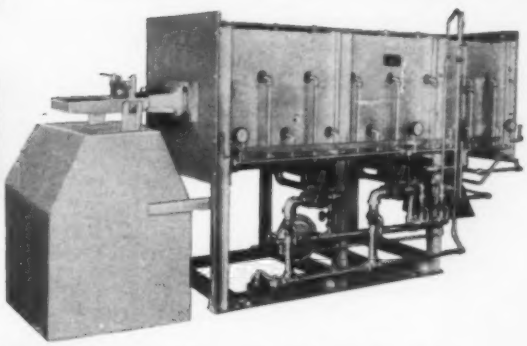
Medium size rotary furnace for the most economical heat treating of parts that can be subjected to a gentle tumbling (approximately ¼ r.p.m.).

Tumbling insures uniform heating and atmosphere contact.

AGF

Model 231

Medium size Shaker Hearth Furnace for the widest range of work, even light and delicate stampings. Momentum imparted to each work piece conveys it individually through the heat with no distortion or warpage.



Capacities to 800 lbs. per hour. Processing pieces from .010" to 1" thickness and up to 10" in length. Automatic continuous feeding reduces direct labor costs drastically! Clean hardening, ammonia-gas case hardening, light case carburizing of steel parts, etc., are accomplished equally well WITHOUT ANY MODIFICATION OF THE FURNACE.

The muffles and retorts are, in reality, radiant tubes WITHIN which the work and atmosphere gas is contained. Zoned combustion systems uniformly heat these muffle tubes from the outside to the desired temperature in each work zone. Control is precise, results uniform.

New catalog of entire AGF line of equipment and accessories now available . . . Write for your copy today.

AMERICAN GAS FURNACE CO.

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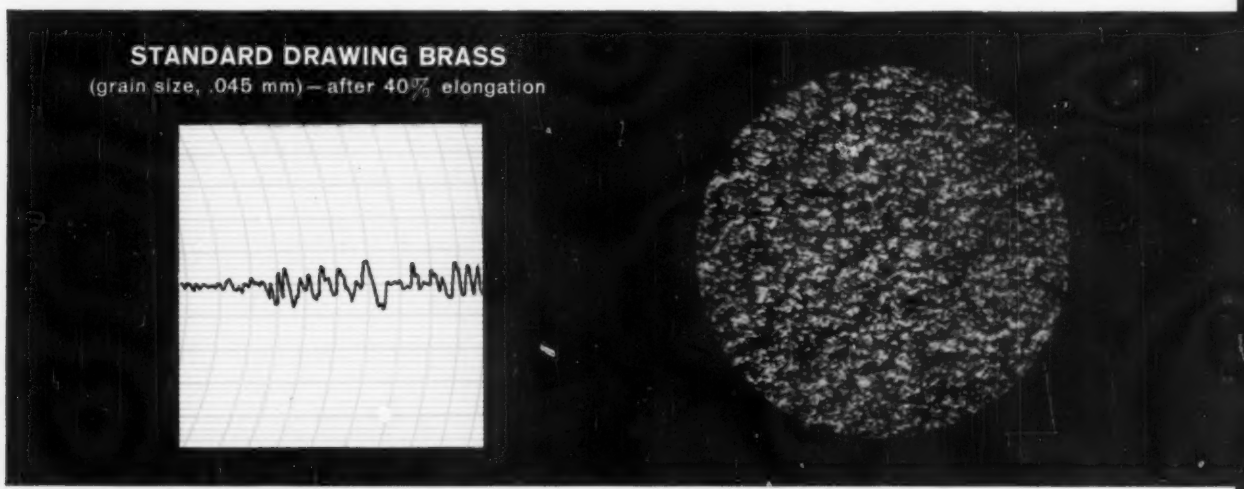
Circle 2401 on Page 48-8

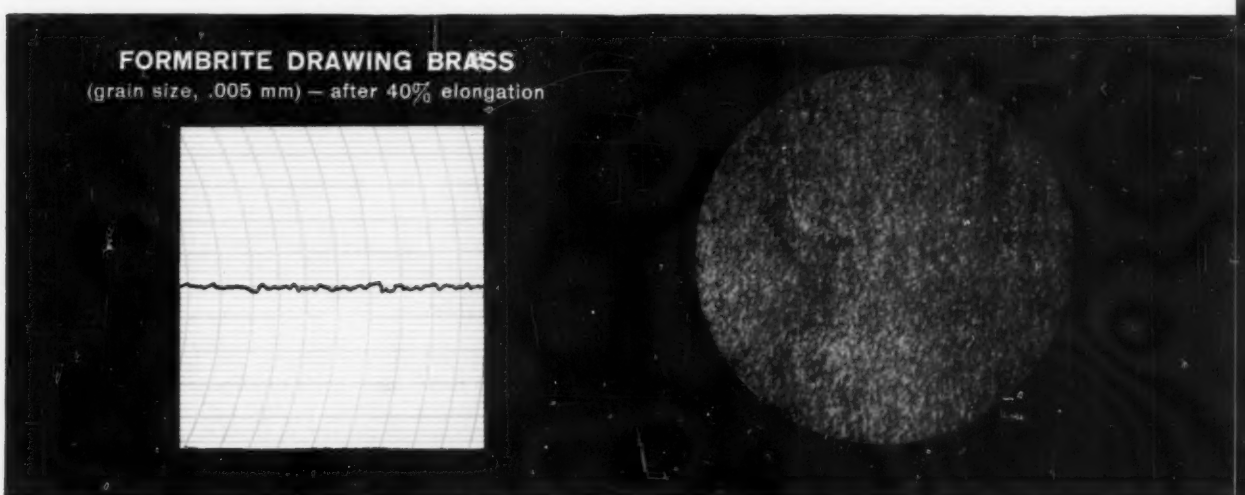
THESE SURFACE TRACES PROVE

when you use Formbrite, Anaconda's superfine-



ENLARGED SURFACE TRACE showing the roughness that causes "orange peel" effect in the working of standard drawing brass. Smoothing such mountains down to the valleys takes a lot of cutting—cost of polishing compounds runs high—production is low—bottlenecks hamstring operations.

THE SURFACE of the stretched standard drawing brass sample looks like this when seen in oblique illumination and magnified 20x. For small deep-drawn products, it might take up to five polishing wheels to finish a surface with roughness of this order—even at low machine speeds.



ENLARGED SURFACE TRACE showing Formbrite's smoothness even after deformation, the test of polishing characteristics of a drawing brass. Little hills like these are easy to level. The trace explains why polishing savings reported by Formbrite users are usually 40% to 50%.

WHEN SEEN IN OBLIQUE ILLUMINATION and magnified 20x under the microscope, the stretched Formbrite surface looks like this. Even in such deep-drawn products as pen caps, only a light cut and a color buff are needed for a jewelers' finish—often a color buff alone does the job.

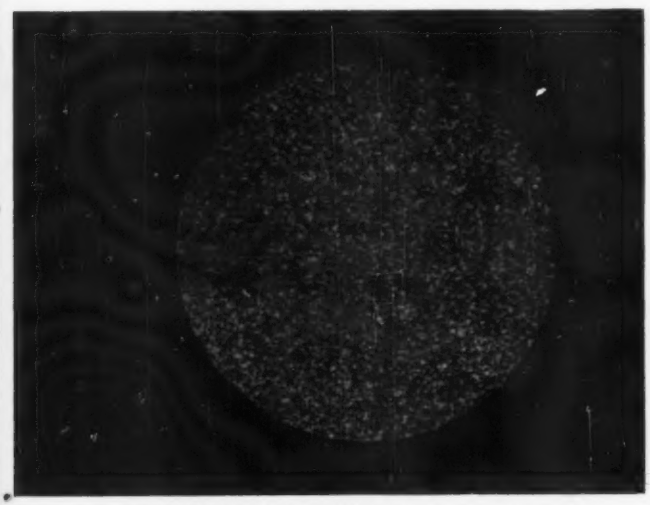
DESPITE its superiority, Formbrite costs no more than standard drawing brass. It is produced in the following brass alloys: Yellow Brass, Cartridge Brass, Gilding, Commercial Bronze, Red Brass, and Low Brass. The Formbrite process is also applied to brass wire alloys for cold-heading and upsetting purposes—for a stronger, springier, more abrasion-resistant product.

Get the full details from your Anaconda representative, or write: Anaconda American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

YOU CAN CUT POLISHING COSTS

grain drawing brass

THIS IS THE MICROSTRUCTURE of the standard drawing brass sample at 75x magnification. The coarse grain structure is typical of the drawing brass that has for decades been used for stamped or drawn brass products. It is the basic reason that polishing costs have run high.



THIS IS THE MICROSTRUCTURE of the Formbrite sample, magnified 75x. The uniform, superfine-grain structure, produced by special procedures of rolling and annealing, explains the relatively smooth surface trace of the stretched Formbrite sample, at the left.

FORMBRITE®

Superfine-grain drawing brass

A PRODUCT OF

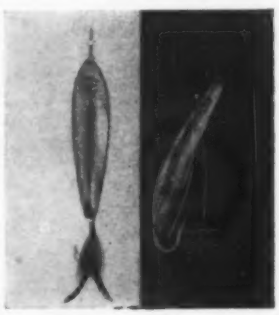
ANACONDA®

ANACONDA AMERICAN BRASS COMPANY

The outstanding feature of Formbrite is easy polishing. But there's something else you should know about it. Formbrite is stronger, harder, springier, and more scratch resistant than the usual drawing brasses. Yet it retains remarkable ductility for forming, stamping, drawing, and embossing. In many instances, these qualities have made it possible to use thinner gage metal.

The maker of this tray, after switching from ordinary drawing brass to Formbrite, found he had achieved a cost reduction of 25% in the cutting operation and 42% in the finish buff—and a healthy boost in production rates.

These fishing lures, first made from ordinary yellow brass, are polished for plating by tumbling. After the switch to Formbrite, manufacturer found he had cut his polishing costs 40%. Small-size formed, drawn, or upset parts made of Formbrite often can be satisfactorily finished by the relatively low cost conventional tumbling methods.



A jewelers' finish on these deep-drawn products meant the use of five polishing heads, with regular drawing brass. With Formbrite, manufacturer uses two polishing heads for a light cut, another for a simple color buff, and runs machines faster. Savings run up to 40%.

When this gage case was made of Formbrite, the instrument manufacturer found he could drop the cutting operation and get a "mirror finish" with a light buff. The saving in finishing cost was 40%.

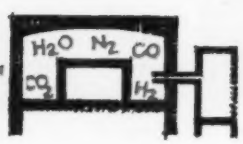
Circle 2402 on Page 48-B

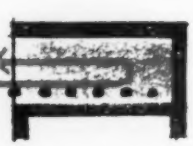
IF you want to HEAT metal . . . .

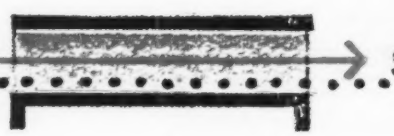
(melting, forging, brazing, sintering or treating) . . . . ferrous, nonferrous or exotic . . . . whether your parts travel one at a time **in batches**

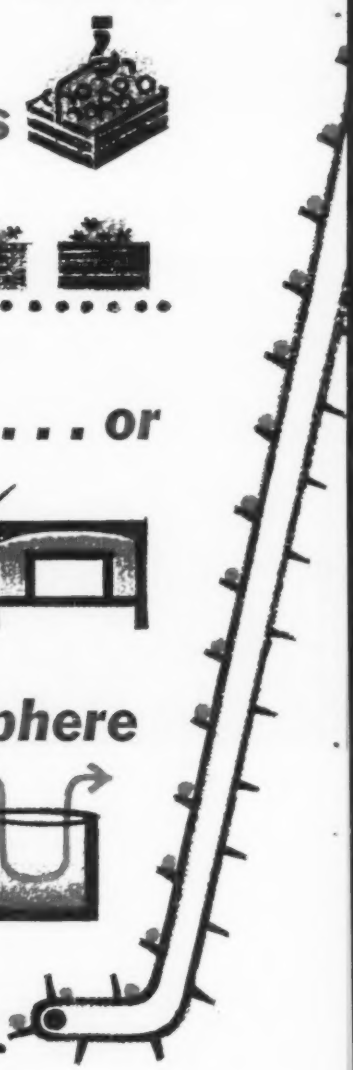
or in droves

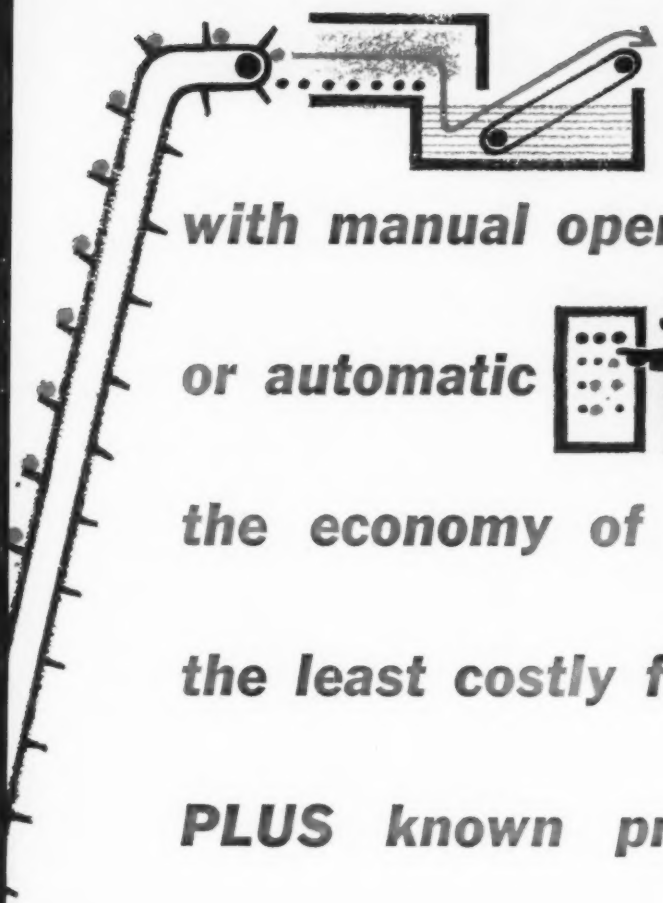
in a straight air atmosphere . . . . or in a protective atmosphere

or 

an upgrading atmosphere in & out  **down & up**

straight through 





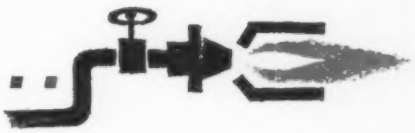
or in a combination

with manual operation

or automatic AND if you want

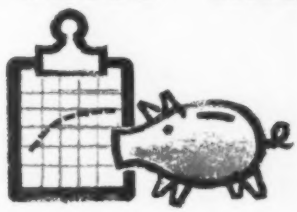
the economy of standard equipment

the least costly fuels . . .



PLUS known production rates and

pre-rated operating costs



WHAT DO YOU NEED? (pit, pot, box, link, muffle, tube, snap or lab furnace)

. . . SURFACE MAKES IT!

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A division of Midland-Ross Corporation

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Circle 2404 on Page 48-B

Gold Coatings

Digest of "How Versatile Application Techniques for Gold Solve Aircraft and Missile Problems", by W. L. Aves, Jr., *Plating*, November 1959, p. 1260-1263.

THE NEED FOR MISSILES to withstand intense heat during flight has prompted engineers to seek the most efficient means for minimizing heat transfer to the missile. One solution: Coat the outer surface of the missile with a highly emissive ceramic coating to radiate friction heat to the atmosphere. The interior is then coated with a low emissive gold finish; this will reduce heat radiation to the payload.

However, vessels to be gold coated usually do not lend themselves to electroplating techniques. The author reports on two alternative methods which have been developed and applied successfully in the missile and aircraft industries.

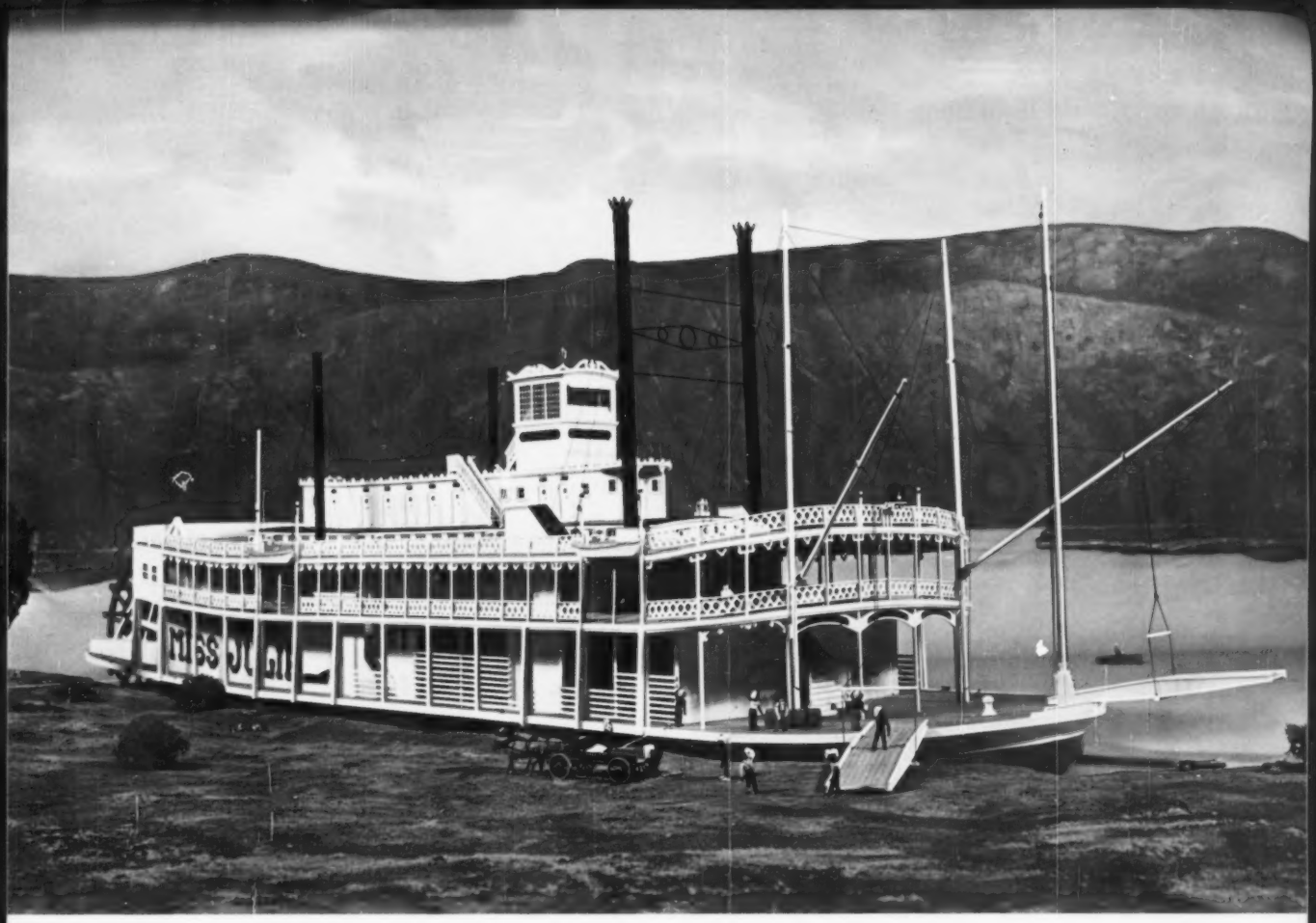
The first of the two processes utilizes a sulpho-resinate of gold dissolved in toluol. It is spray-coated onto the carefully cleaned surface, air dried, baked at 375° F. for 15 min., and thermally decomposed by heating for 1 hr. at 700° F. in air.

A second method, used principally to coat electrical printed circuits and contacts, relies upon ionic displacement in a nonelectrolytic immersion process. Carefully cleaned parts are immersed 5 min. in a commercial immersion gold solution containing ½ troy oz. of gold per gal. Bath temperature is maintained between 120° and 160° F., and pH between 7 and 8. Ammonium hydroxide is added as necessary to adjust the pH.

Gold coatings may be applied to Type 321 stainless steels by the first method without difficulty. However, toolsteels, aluminum, magnesium, copper, and chromium-base alloys must first be plated with nickel before applying the gold. It may also be applied over ceramic coatings, which are used as a diffusion barrier if the vessel is likely to be exposed above 1500° F.

Typical coatings vary in thickness from 0.000002 to 0.00001 in. Material costs are about 10 to 60 cents per sq.ft. of surface, making gold coatings economical for use as a heat barrier in critical military vehicles.

J. L. WYATT



OHIO Special Quality Tubing makes muscles that never tire

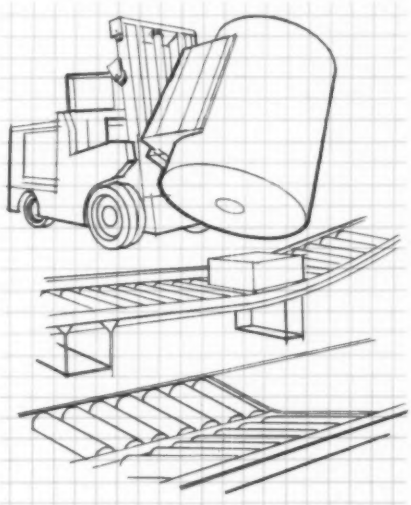
Strength, weight and cost advantages of OHIO Special Quality Tubing make it ideal for use in materials handling equipment — the modern lift trucks, belt and roller conveyor systems that provide the heft and muscle to move materials.

You can strengthen your product, too, if you weigh these important facts. OHIO Tubing is always the exact tubing you need because OHIO Tubing is CUSTOM MADE for your product. Your order is manufactured to your own specifications to produce steel tubing especially for your application — the precise grade, analysis, size, shape, special anneal and tolerances best suited to your needs.

Ohio Seamless Tube produces both seamless and electric welded steel tubing — is prepared to form many finished or semi-finished tubular parts to your designs.

To get the most from your next steel tubing order, specify OHIO Special Quality Tubing. Contact your nearest Ohio Seamless representative, or send part drawings to the plant at Shelby, Ohio — Birthplace of the Seamless Steel Tube Industry in America.

A-3291A



Model illustrated built to 3.5 mm scale.

OHIO

OHIO SEAMLESS TUBE

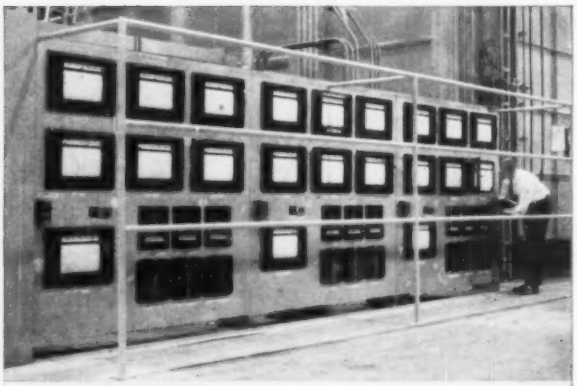
Division of Copperweld Steel Company • **SHELBY, OHIO**

Seamless and Electric Resistance Welded Steel Tubing • Fabricating and Forging

SALES OFFICES: Birmingham, Charlotte, Chicago (Oak Park), Cleveland, Dayton, Denver, Detroit (Huntington Woods), Houston, Kansas City, Los Angeles (Lynwood), Miami, Moline, New Orleans (Chalmette), New York, Philadelphia (Wynnewood), Pittsburgh, Richmond, Rochester, St. Louis, St. Paul, Salt Lake City, Seattle, Tulsa, Wichita

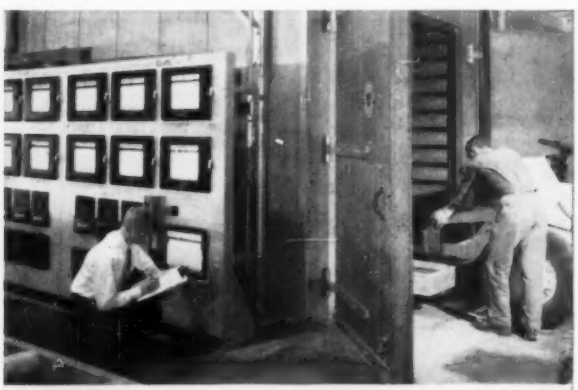
CANADA: Railway & Power Engr. Corp., Ltd. EXPORT: Copperweld Steel International Company, 225 Broadway, New York 7, New York

SOAKING. These Bristol Dynamaster* instruments monitor soaking pit operation in new, multi-million-dollar aluminum fabricating plant of Anaconda Aluminum Company at Terre Haute, Indiana. Staff engineer analyzes record.



ANNEALING. Dynamaster* instruments here control and record annealing furnace temperatures in new Anaconda Aluminum plant. Over 11½ acres under one roof, the new plant produces aluminum sheets, extrusions, tubes and ingots.

HEAT TREATING. Anaconda staff engineer checks temperature records, produced by Bristol Dynamaster instruments, for vertical extrusion heat-treating tower, part of which is shown at left.



AGING. Dynamaster instrument panel at left controls and records temperatures in aging furnaces in new Anaconda Aluminum Company plant. Furnace operator at right is moving rack car into furnace.

BRISTOL INSTRUMENTS FOR THE METAL INDUSTRY

The key to higher quality, more uniform production, greater efficiency

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Bristol Dynamaster* electronic potentiometer pyrometers, service-tested and proved in thousands of industrial plant installations, fully measure up to the requirements of today's most advanced steel and metal-working plants. Check these modern features:

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Write for complete data—and remember, Bristol markets a complete line of pyrometer accessories available for fast delivery to keep your plant in operation. The Bristol Company, **106** Bristol Road, Waterbury 20, Conn. *T. M. Reg. U. S. Pat. Off.

BRISTOL ...for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Copper Alloy Bulletin

BRIDGEPORT BRASS COMPANY

new BRIDGEPORT NIRONZE® 635 gives 90,000 psi yield strength

90,000 psi Yield Strength Obtained with New Age-Hardenable Copper-Nickel-Silicon Alloy

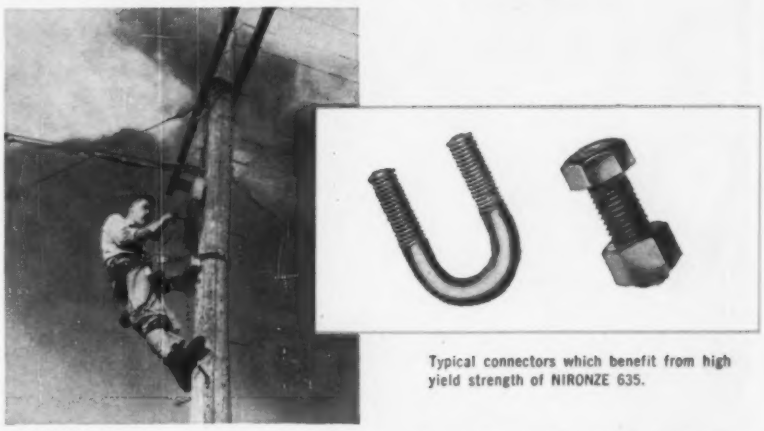
Bridgeport Nironze 635, an age-hardenable copper-nickel-silicon alloy, combines excellent cold-working properties with high tensile and very high yield strengths, good electrical conductivity, excellent general and stress-corrosion resistance. Supplied in the solution-treated and drawn condition, Nironze 635 offers exceptional cold-working properties. A low-temperature heat treatment, following additional cold-work age, hardens this alloy to produce tensile strengths of 100,000 psi, yield strengths of 85,000 psi and improved electrical conductivity of a minimum of 35% IACS.

Easily Cold-Formed ... Machined

The excellent cold-working properties of Nironze 635 in the *solution-treated and drawn* condition allow such severe cold work as upsetting, cold-heading, roll-threading, bending, forming or similar operations to be carried out with ease. Heat treatment following this cold-work age-hardens this alloy to produce maximum tensile and yield strengths.

Nironze 635 in the *solution-treated-drawn-aged* condition has a machinability about 30% of free-cutting brass rod, thereby making it possible to carry out such conventional machining operations as sawing, grinding, turning, milling or similar operations.

Maximum cold-work may be performed on Nironze 635 in the *solution-treated* or soft condition. In order to obtain highest possible physical properties, this alloy must be cold-worked from 50-80% before aging.



Typical connectors which benefit from high yield strength of NIRONZE 635.

Proved by Performance in These Applications

Cold-headed bolts and fasteners used in pole line hardware, switch gear, wire connectors, neon signs, railway equipment, exposed electrical parts and structural supports, marine hardware and fittings can all use Nironze 635 to advantage. The new alloy's unique combination of high yield and tensile strengths, good conductivity and high corrosion resistance provides design and production advantages never before offered by a silicon bronze.

Test a Sample Now

Nironze 635 has been thoroughly evaluated in the laboratory and in the field to insure the high quality and top performance common to all Bridgeport alloys. To get your test samples and full technical information, call your nearest Bridgeport Sales Office. Or write us direct. Dept. 4112.

Nironze 635 is presently available as rod or wire, supplied in the solution-treated, solution-treated and drawn, and solution-treated, drawn and aged.

NIRONZE PHYSICAL PROPERTIES

Density	0.320 lb/in.³
Color Red	similar to copper
Thermal Expansion	8.9 x 10–⁶/°F
Melting Point	1990°F
Nominal Composition:	
Copper	97.5%
Nickel	1.9%
Silicon	0.6%
Total	100.0%
Electrical Conductivity, % IACS	
Cold-drawn and aged	30%
Cold-drawn	15%

MECHANICAL PROPERTIES (Nominal)

Form	Condition	Tensile Strength psi	Yield Strength psi	Elongation % (4D)	Contraction of Area %	Rockwell B Hardness	O/O IACS
Rod and Wire	Solution-Treated	40,000	12,000	50	90	7	24
	Solution-Treated, Aged	88,000	70,000	12	20	86	43
	S.T. Drawn 50%	65,000	62,000	18	87	67	22
	S.T. Drawn 50%, Aged	100,000	90,000	12	25	95	42
	S.T. Drawn 80%	70,000	65,000	15	85	73	22
	S.T. Drawn 80%, Aged	103,000	97,000	17	62	96	39

COMPARATIVE RATINGS OF NIRONZE 635 vs STANDARD SILICON BRONZES

	Physical Properties: Electrical Conductivity (Annealed) % IACS	Physical Properties: Melting Point Liquidus °F	Physical Properties: Density lb/in.³	Fabrication Properties: Cold Workability	Fabrication Properties: Machinability Rating %	Fabrication Properties: Annealing Temp. °F	Mechanical Properties: Tensile Strength psi	Mechanical Properties: Yield Strength psi	Mechanical Properties: Rockwell B Hardness
NIRONZE 635	*35	1990	0.320	Excellent	*30	**850-900	100,000	85,000	95
High Silicon Bronze (A)	7	1880	0.308	Excellent	30	900-1300	108,000	60,000	95
Low Silicon Bronze (B)	9	1940	0.316	Excellent	30	900-1250	90,000	67,000	90

The term "Nironze" is a registered trade-mark of the Bridgeport Brass Company

*Drawn and aged **Aging temperature

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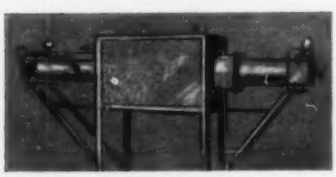
Circle 2366 on Page 48-B

for temperatures as high as 1950° C. (3542° F.)

99.7% pure, smooth, impervious, recrystallized alumina tubes

Now Morganite's Triangle RR impervious recrystallized alumina tubes are available in sizes up to 4½" I.D. (5" O.D.). These new large bore tubes are being used in molybdenum wound tube furnaces both for production and research.

Morganite's furnace tubes are available open both ends or hemispherically closed on one end. They are 99.7% pure alumina—no binders added; ideal where freedom from contamination is essential.



Their smooth, hard, dense interior surface prevents tube abrasion. Lengths up to 48".

For temperatures up to 1900° C. (3450° F.) Morganite's new Triangle R **porous**, pure alumina tubes are also available. Sizes range up to 6" I.D. x 48". Open both ends.

Write for technical data, or call STillwell 4-3222

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Circle 2406 on Page 48-B

Segregation in Chromium Steel

Digest of "Influence of Delta Ferrite-Carbide Segregates on the Mechanical Properties of Modified 12% Chromium Steel", by E. A. Loria. Preprint No. 242, 1961. Paper to be presented at the National Metal Congress, Detroit, October 1961.

THIS INVESTIGATION was intended to show the influence of delta ferrite-carbide segregates on the mechanical properties of 12% Cr-Mo-W-V steel (Type 422). Smooth and notched tensile, stress-rupture, impact and fatigue tests were made in both the longitudinal and transverse directions. The physical data obtained were correlated with the amount and distribution of the ferrite-carbide phase. By properly balancing the composition, steel could be produced free of ferrite in ingot sizes up to 26 in. in diameter. However, undesirable nonmetallics, massives carbides and ferrite-carbide aggregates were present in large forgings processed from ingots 36 to 55 in. in diameter. Photomicrographs in the paper illustrate this.

Up to 5% delta ferrite is not detrimental to the tensile properties obtained in either direction. Banded ferrite in greater amounts, however, reduces transverse elongation and reduction of area by more than 50%. For example, a steel containing 5% banded ferrite had 15% elongation and 29% reduction in area, while one containing 15% had elongation and reduction in area values of 8 and 12, respectively. A small amount of discontinuous type ferrite is beneficial in that it lowers the amount of precipitation in the former austenite boundaries and promotes grain refinement.

Massive carbides, nonmetallics and ferrite-carbide segregates drastically lower tensile properties irrespective of testing direction. Once formed, these complex segregates are not easily removed by high-temperature homogenization treatments because they cannot be diffused; they reprecipitate upon tempering or slow cooling.

After tempering at 1350° F., the longitudinal Izod impact values decreased with increasing amounts of banded ferrite. Also, banded ferrite drastically lowered transverse impact values.

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e. techniques for multi-thickness specimens.
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Circle 2408 on Page 48-B

Segregation . . .

Below 18% ferrite there was no apparent effect on the longitudinal stress-rupture properties of specimens tempered at 1200° F. and tested at 1000° and 1100° F. When more than 8% banded ferrite was present, the transverse rupture strength at 1100° F. was lowered, this being reflected by an estimated 32 to 70% decrease in time to rupture when stressed at 62,000 to 65,000 psi.

As much as 5% ferrite was not detrimental in longitudinal fatigue tests made at 500° F. on plate and bar stock treated to the 200,000 psi. tensile level. Bar stock heat treated to the 145,000 psi. tensile showed a decrease in longitudinal fatigue when more than 15% banded ferrite was present. W. R. Opie

Information Searching

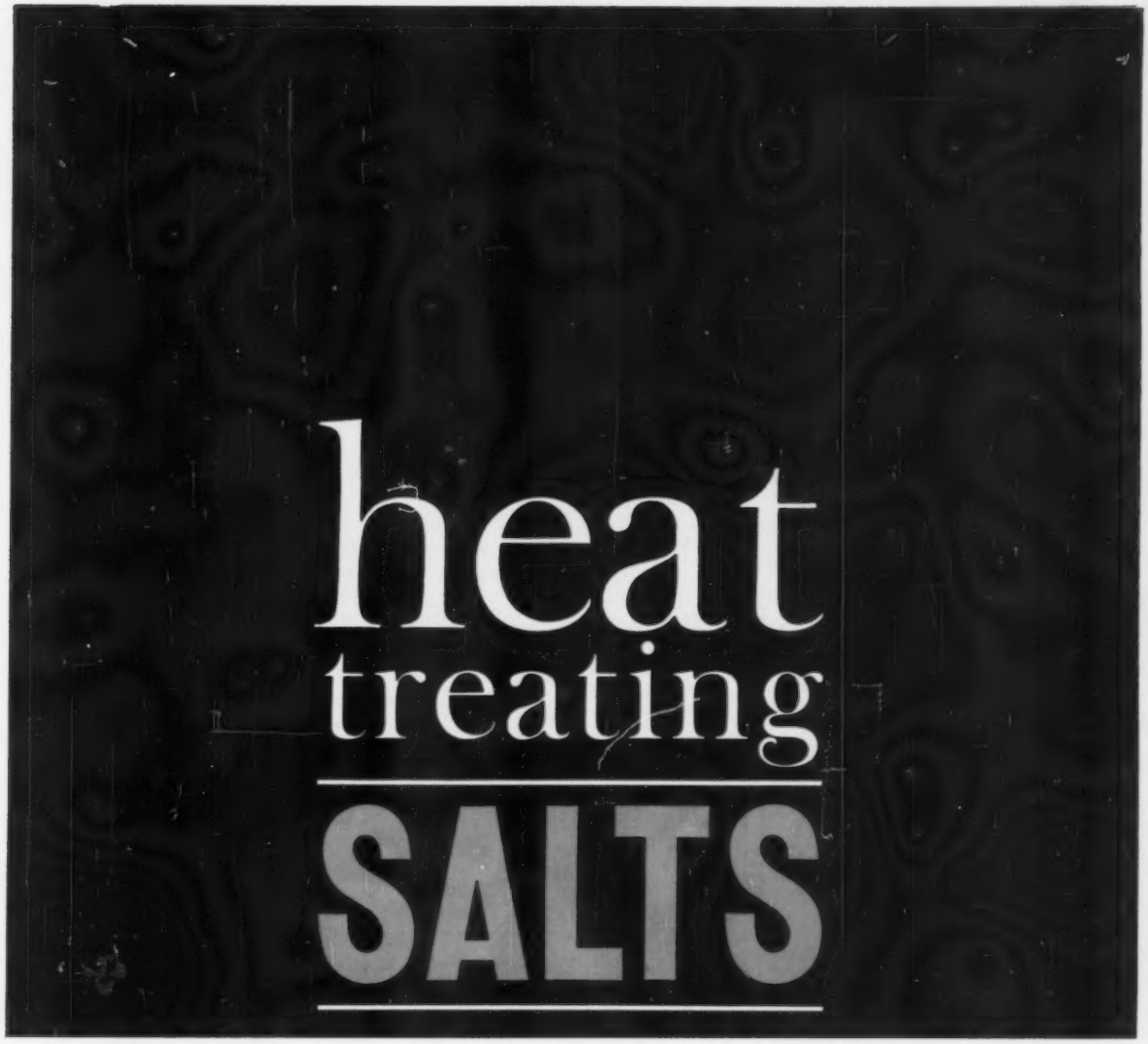
Digest of "Machine Literature Searching—From Experiment to Experience", by Marjorie R. Hyslop. Paper presented before the Joint Meeting of Councils of Librarians, East and West Coast Navy Laboratories, held in Washington, D.C., Oct. 5, 1960.

The Information Searching Service of the American Society for Metals, in operation since January 1960, provides guides to sources where specific information is available from the current literature. Abstracting and encoding of current literature is going on at the rate of 35,000 documents per year (about 3000 per month). A "backlog" of 12,000 abstracts from 1958 and 1959 has also been encoded.

Typically, searches are run at two-week intervals. The electronic searching machine "looks at" 1500 new abstracts per search, and selects those that are pertinent to the subscriber's literature-searching requirements. Copies of the selected abstracts – brief indicative outlines of the contents of the document – are immediately sent to the subscriber.

Since January 1960, 40 subscriptions have been received. Listed below are some of the topics being covered.

1. Mechanical and physical properties at low temperatures
2. High-velocity deformation of metals



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Circle 2409 on Page 48-B

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Searching . . .

3. Vacuum melting and casting
4. Machinability of heat resistant alloys
5. Magnetic materials
6. Explosive forming
7. Powder processing
8. Fuel rods for reactors
9. Rare earths

As of August, 261 separate searches have been run, resulting in the delivery of 4828 abstracts.

The amount of detail and the rigid specifications that can be applied to a typical search are illustrated by the following example (search requirements for Item 1 above):

Materials

Aluminum-base alloys: Tens-50, 356, 1100, X 2020, 2024, 6061, 7075

Cobalt-base alloys: Elgiloy, Stellite 3, Stellite 25

Copper-base alloys: Berylco 25, 70-30 brass, copper

Iron-base alloys: Invar 36, 34% Mn steel, Ni-Span C, Vascojet, 17-4 PH, 17-7 PH, A-286, 301, 302, 303, 304 LC, 310, 321, 347, 410, 416, 440 C, 1070, 2800 (9% Ni), 4340

Nickel-base alloys: Inconel, Inconel "X", "K" Monel, "S" Monel, nickel, René 41

Titanium-base alloys: A-110-AT, B-120-VCA, C-120-AV

Carbides: Titanium carbide, tungsten carbide

Nonmetals: ice, Kel-F, mylar, nylon, teflon

Other metals: beryllium, molybdenum

Properties (—423 to +500° F.)

Yield strength, tensile strength, elongation, reduction of area, stress-strain diagram, modulus of elasticity, impact energy, hardness, compressive strength, shearing yield strength, shearing strength, modulus of rigidity, fatigue behavior, creep behavior, expansivity, Poisson's ratio, thermal conductivity, mechanical hysteresis, electrical resistivity, magnetic properties, compression set, compression modulus, flexural strength, flexure modulus.

The subscriber is interested in nine classes of materials (naming trade names and alloy designations) and he wants data on 25 properties of these materials in the temperature range —423 to 500° F. This is the sort of thing that the electronic searching machine can handle with ease.

Table I shows the results of some typical searches; for example, the very exacting low-temperature property search (discussed above) re-

Table I — Results of Some Typical Searches

Subject	Searches*	Period Covered	Citations Retrieved
Low-temperature properties	18	8 mo.	251
Vacuum melting and casting	17	8	286
Machinability of high alloys	17	8	278
Magnetic materials	14	6	284
Rare earths	2	1	72

*At two-week intervals.

Table II — Comparison of Machine Retrieval to Scanning of Abstract Indexes

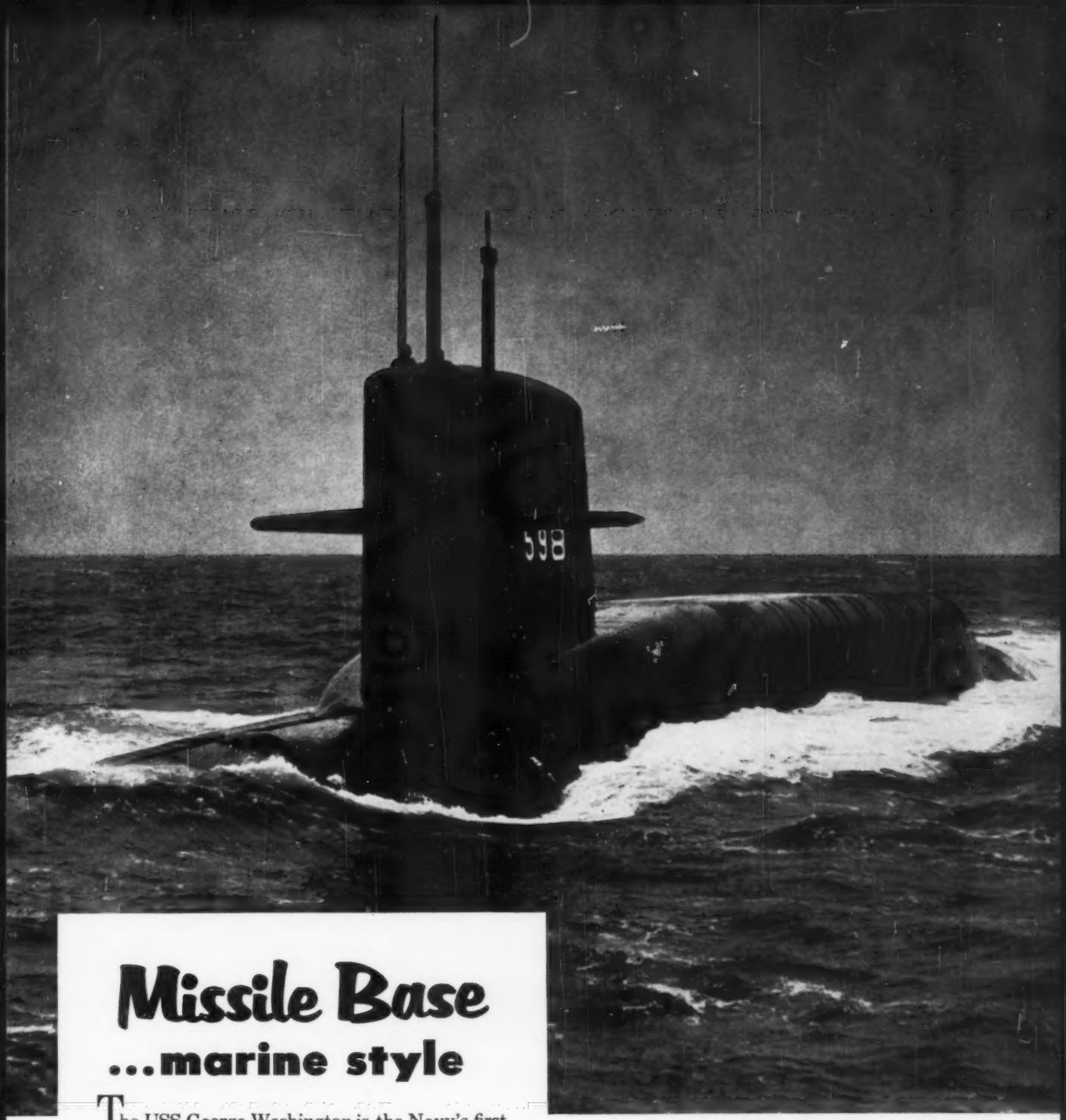
Subject	Machine Search (*a*)	R.M.L. (*b*)	E.I. (*c*)	Met. Abs. (*d*)
Low-termperature properties	364	26	42	—
Vacuum melting and casting	442	63	37	—
Machinability of high alloys	416	35	16	—
Magnetic materials	520	65	295	19
Rare earths	936	81	48	24

(*a*) A.S.M. Information Searching Service abstracts delivered during 1960 subscription period, extrapolated to a full year.

(*b*) *Review of Metal Literature*, Vol. 16, 1959 (scanning of subject index).

(*c*) *Engineering Index*, 1959 (scanning abstracts under appropriate subject headings).

(*d*) *Metallurgical Abstracts*, Vol. 25, 1958-1959 (scanning subject index).



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Circle 2410 on Page 48-B

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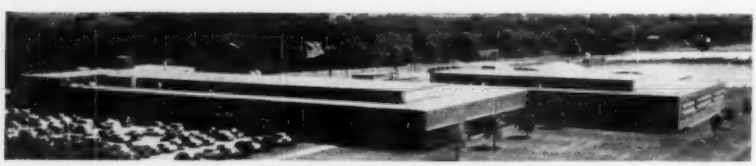

aluminum and ductile iron castings

BEAN

Circle 2411 on Page 48-B

Searching . . .

trieved 251 citations in eight months.

As Table I indicates, an almost fantastic amount of information was amassed over a short period of time. These machine-searching results were compared with conventional searches through the indexes of abstracting services. Table II shows that more than ten times the amount of information was retrieved by machine searching; it also points up another advantage – the availability of "immediate indexing" (1960 vs. 1959) with machine literature searching.

Experience to date has convinced everyone concerned with this project that machine searching is better, faster, more up-to-date, more complete, and above all, cheaper than other services based on traditional library methods. F.L.S.

Simplified Cathodic Etching Equipment

Digest of "Cathodic Bombardment Etching of Nuclear Materials", by D. Armstrong, P. E. Madsen and E. C. Sykes, *Journal of Nuclear Materials*, Vol. 1, No. 2, July 1959, p. 127-135.

ETCHING of metallographic samples by cathodic rays was suggested by Cyril S. Smith in 1927 but perhaps the first large use was made 20 years later by D. M. McCutcheon and W. Pahl in Ford Motor Co.'s laboratories (see *Metal Progress*, November 1949, p. 674). The practice has more recently become almost standard for the study of uranium alloys and other refractory metals. The present authors who are connected with the United Kingdom Atomic Energy Research Establishment describe a rather simplified apparatus which seems to work quickly on samples of all kinds. For example, low-carbon steel requires only 2 min. bombardment. (Compare 100 min. suggested by McCutcheon and Pahl.)

The sketch indicates the equipment. Its principal variation from other designs is the possession of a pyrex inner tube, about 3 in. diameter by 15 in. long (although dimensions do not appear to be critical) which gives an even flow of gas through the chamber. High-tension

Cathodic Etching . . .

supply very similar to that for an X-ray set is used. The cathode and sample are cooled, if thought necessary, by dripping liquid air or nitrogen on the brass base plate.

The specimen is placed face up as the cathode and the bare remainder covered with zirconium foil. The chamber is evacuated (with a rotary pump) to 30 to 50 microns, and dried tank argon admitted in slowly increasing stream. Voltage of 1500 is then applied; pressure rises rapidly to about 80 microns, but is then steadily reduced by continued pumping. Meanwhile voltage is increased to 4000 to 4500 (correct range for all but a few fusible metals) and etching starts. Etching current is most easily controlled by slight alterations in the gas supply. The magnetic coil is to generate a field of about 100 oersted, which

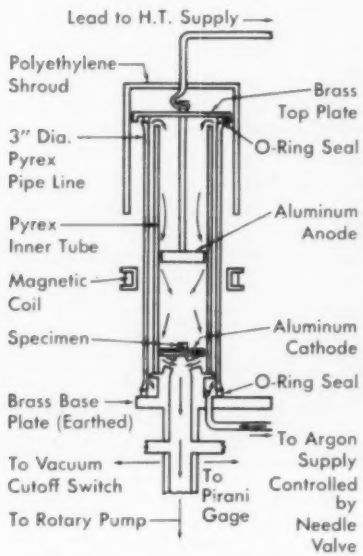

Fig. 1—Cross Sectional Sketch of Etching Chamber. Arrows inside apparatus indicate direction of argon flow

curves the electron path, ionizes more gas atoms, increases the current flowing to the cathode, and decreases the etching time.

Proper etching will develop grain boundaries and twin bands, but give little contrast between grains. Inclusions are not changed or removed — one of the main advantages of the method. Several specimens of the same material can be etched simultaneously as long as they are about the same height or thickness. Fairly good contact is necessary between specimen and cathode, principally to keep the specimens cool (below 100° C.). Prior mechanical polish of high grade is necessary. Also, any flowed surface layer must be avoided.

An extensive table of etching conditions for a wide variety of metals and alloys is included in the article. E. E. T.

Sparks and Safety

Digest of "Sparking Characteristics and Safety Hazards of Metallic Materials", by Harold Bernstein and G. C. Young, Navord Report 5205, U.S. Naval Gun Factory, April 8, 1957.

ACCORDING TO THE AUTHORS, nonsparking tools, used by the U. S. Navy where flammable and explosive substances are handled, are deficient in strength and durability. The present survey was made to provide

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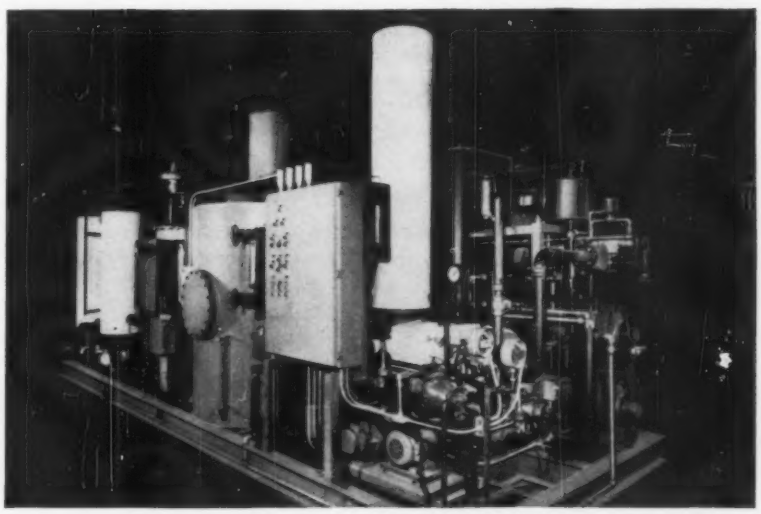

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Circle 2412 on Page 48-B

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Republic Steel—largest producer of the nation's widest range of bar products—has a new, 11″ bar mill in Chicago that specializes in steel for cold extrusion and cold heading. Features that save you money:

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4 **1600-POUND, DOUBLE-BANDED COILS**--four high-speed coilers handle the complete range of coils produced (⅛″ to 89/64″—700 to 900 pounds, ⅜″ to 1½″—1400 to 1600 pounds). Bigger coils cut downtime and scrap loss. Double banding simplifies your handling.

5 **CAPACITY TO MEET YOUR REQUIREMENTS**—this 11″ bar mill produces bar products at rates of up to 3000 feet per minute. Annealing furnaces are the continuous type, capable of meeting the growing demand for furnace-processed steel.

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Depending upon the nature of your product and the method by which it is made, you may find it more advantageous to use cold extrusion quality steel in *cold finished form,* as did the manufacturer of this gear.

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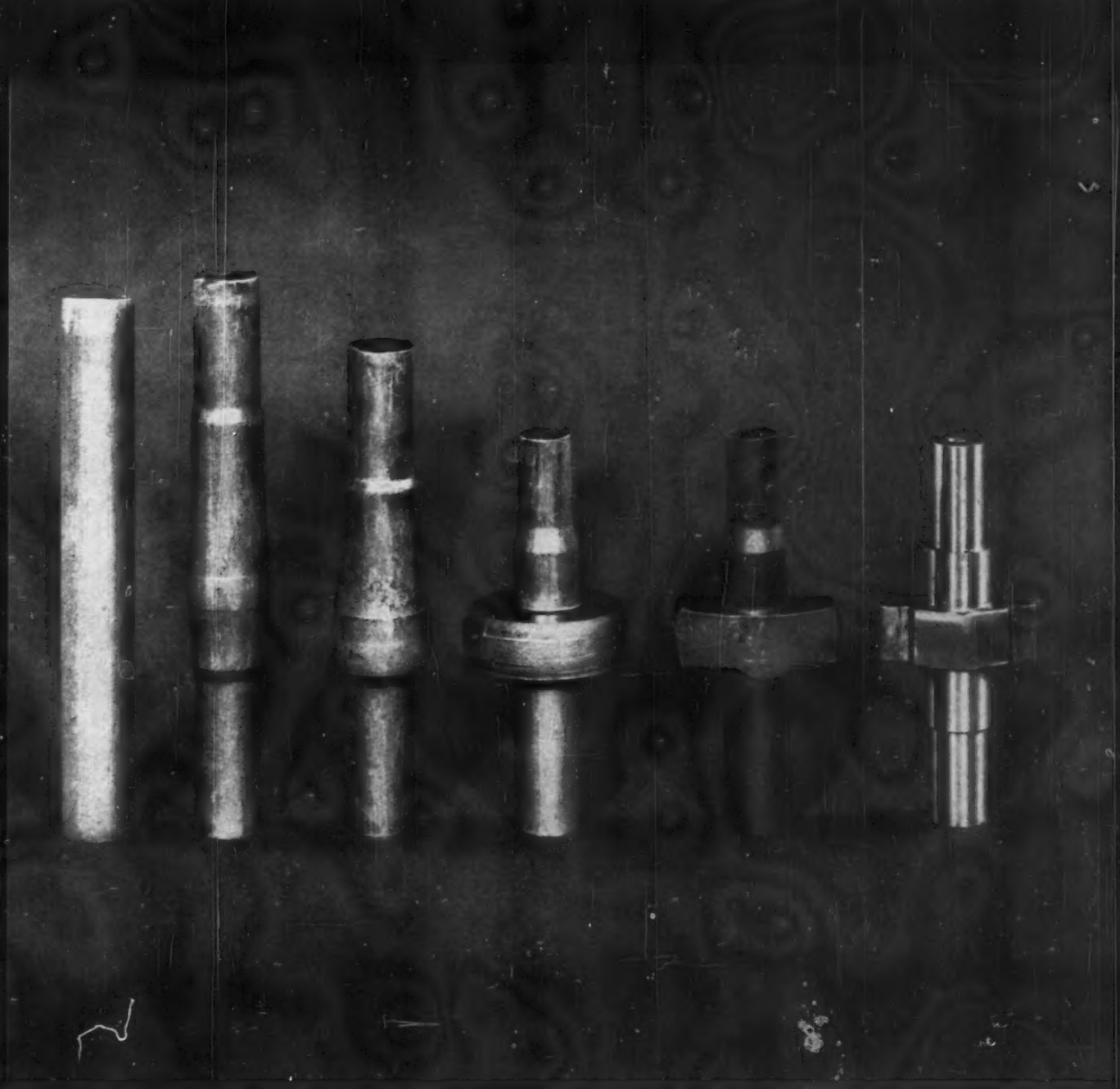

CUTTING THE COST OF A SEGMENT GEAR: ideal blanks are produced by cold heading, cold extrusion, and upsetting. Stock with upset in the center is hot trimmed on a press, after which it is machined into the finished part. Only a minimum of stock need be removed during final machining. Photo courtesy of National Machinery Company, Tiffin, Ohio.

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Circle 2414 on Page 48-B

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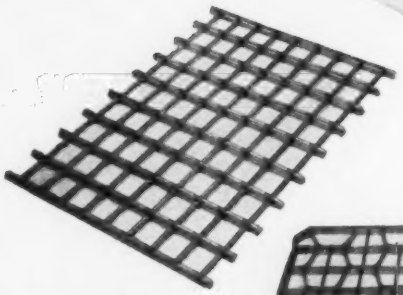

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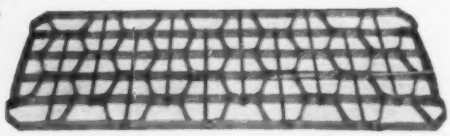
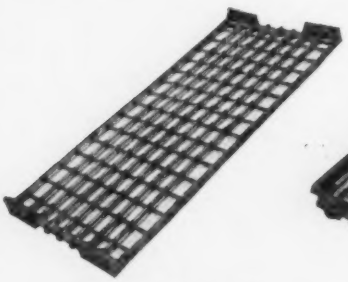
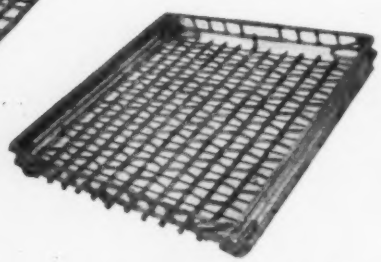


"Serpentine"



"Pressure Welded"
with pusher pads



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Rolock has done more, we believe, than anyone else in the field to *originate* improved design and construction features that have consistent practical value to the heat treater.

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Circle 2415 on Page 48-B

Sparks and Safety . . .

information on sparking characteristics of material and the ignition hazards of friction sparks.

There are at least three types of sparks – friction sparks, impact sparks and electrical sparks. Friction sparks result when two hard materials come into forcible contact. A particle is sheared off, mechanical energy is converted into heat, and the freshly exposed surface of the particle oxidizes. When there is enough heat, the particle reaches the incandescent point and becomes a spark. Such sparks may be classed as low energy (from hand tools) or high energy (from mechanical tools).

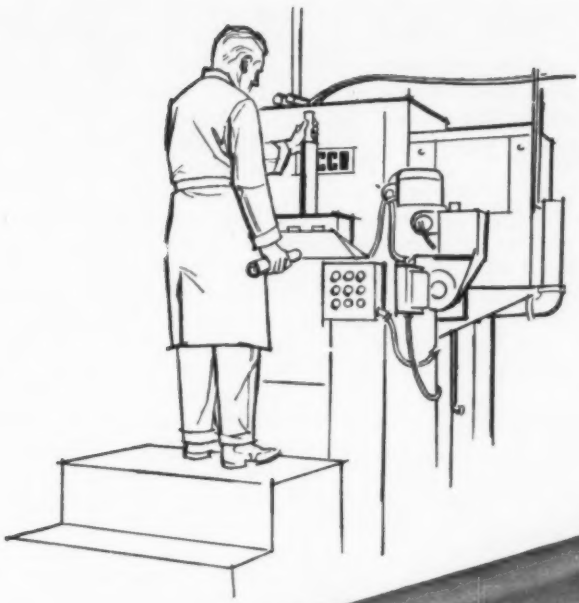
Impact sparks are produced by impact on a quartzitic-type rock. Quartz is piezo-electric and can convert mechanical into electrical energy. As before, particles of the impacted material are thrown off, but these particles do not oxidize in air, and therefore will lose heat.

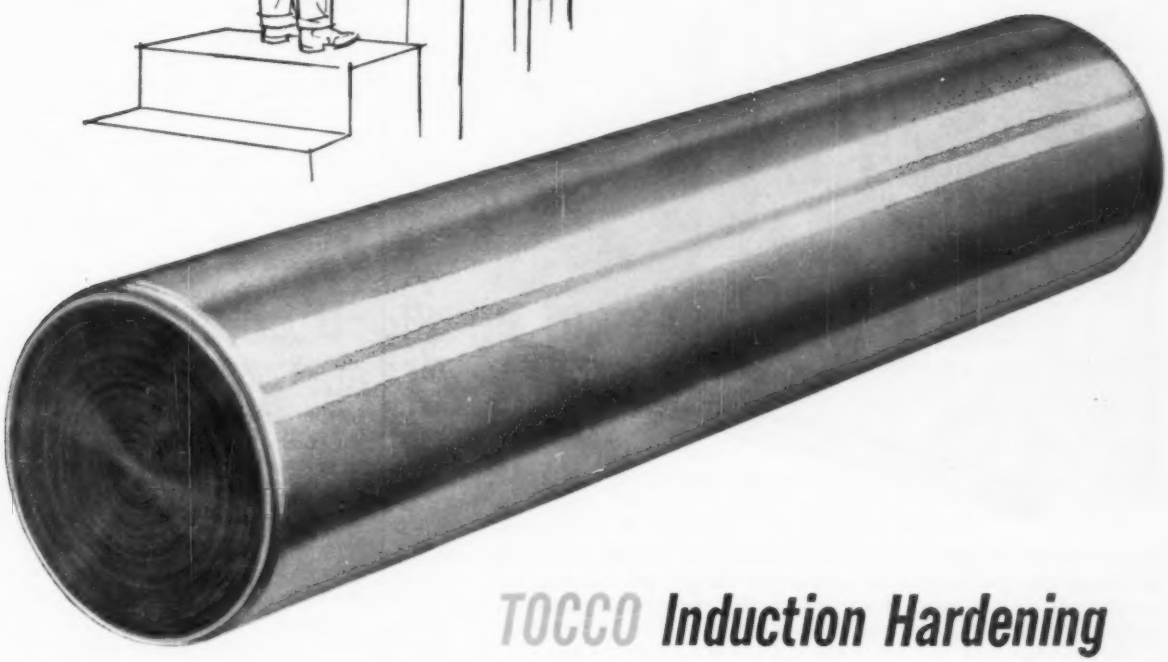
Electrical sparks accompany a sudden, disruptive discharge between two bodies with different potentials, but are not considered further in this report.

The results of many tests support the theory that friction sparks are due to oxidation. Brass, an oxidation resistant material, produced only a few dull red sparks when held against a grinding wheel. Certain oxidation resistant alloy steels produced brighter red sparks, while plain carbon steel gave large quantities of white sparks. Tests in oxygen-deficient atmospheres indicated that the initial impact or friction started the temperature rise, but that the principal heating resulted from oxidation.

For spark ignition to occur, three factors must coexist: The flammable material must be vaporized or very finely divided, the material must be present in certain definite proportions with air, and enough heat must be available to initiate the flame and cause it to propagate. The more common combustible hydrocarbons ignite from 200° F. upward, but the majority seem to lie between 450 and 750° F.

Another important factor is particle size. It has been found that the steel sparks which were very small would not ignite gasoline vapors. Although their temperatures





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The Eimco Corporation of Salt Lake City are producers of heavy-duty earth moving and mining equipment. They recently replaced a low production induction hardening method with a modern, more efficient track pin hardening machine engineered and built by TOCCO for high production operation.

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Circle 2416 on Page 48-B

Sparks and Safety . . .

ranged between 2300 to 2500° F., they did not hold enough heat to start the flame. Experiments with several metals have shown that the particle size required for ignition of methane-air mixtures decreased as the heat of combustion increased.

Gas ignition can also result from impact alone, as for example between steel and siliceous sandstone. In this instance, however, ignition starts from heating at the surface of the rock and not friction sparks.

Testing methods used were:

1. Abrasive wheel – a piece of metal is held against a rapidly revolving abrasive wheel to produce a stream of sparks.

2. Drop weight – A brass weight, with a disk of the test metal attached, falls vertically on an inclined steel plate. Ignition is most easily obtained with light alloys striking a rusty steel plate at angles of 35 to 55°. Materials can be compared by determining the impact energy needed to produce a given ignition probability.

3. Ballistic – Steel balls are projected at 500 to 3000 ft. per sec., and pass through a cellophane window of an explosion chamber (filled with gas) to impact on the target material.

4. Sliding rod – A steel cylinder, with a replaceable hardened steel nose, slides down an inclined guide to hit the specimen on which a standard weight of explosive has been placed. The height of drop is varied to determine the minimum which will give 50% detonation in 20 specimens.

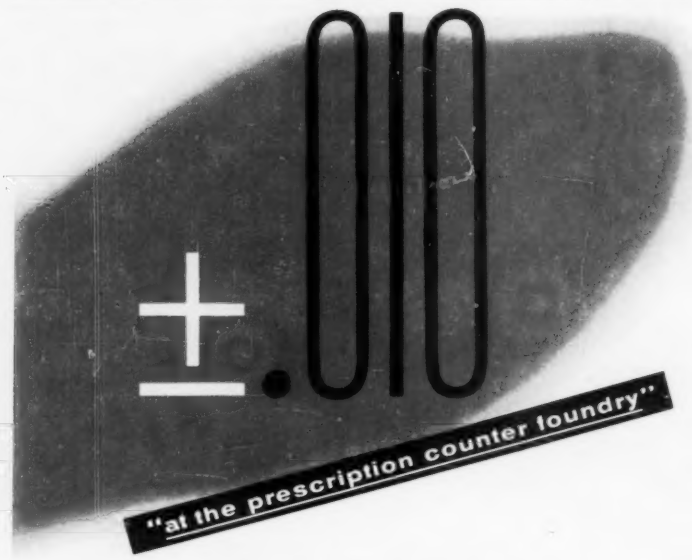
With metal on stone the metal seems to matter little; the stone is the controlling factor. In particular, quartzitic sandstone and rock containing pyritic inclusions are dangerous. The ballistic impact of steel or brass on sandstone produces no hazards in methane-air, but great hazards in hydrogen-air mixtures. Grinding wheel sparks from various grade steels offer no ignition hazard in gasoline vapor, but are a danger in carbon bisulphate.

The impact of steel on steel, zinc and aluminum bronze in methane atmospheres is not an ignition hazard in the drop weight test; impact of the same materials is a moderate hazard in methane-air, and a considerable hazard in hydrogen air.

The impact of light alloys on rusty steel in the drop weight test produces ignition hazards in both methane and pentane; the hazard increases with the magnesium content. It is important to note, however, that high energy levels, as compared to manpower, are required to produce ignitions in the metal-to-metal impact test.

The impact of hand tools on aluminum coatings or smears on rusted steel is a source of considerable hazard in methane atmospheres. This is believed to be a thermit reaction between aluminum and rust.

Finally, it is pointed out that the number of substantiated ignitions due to metallic sparks from hand tools is extremely small, although the same cannot be said of mechanical tools. Occurrences are on record where "nonsparking" tools have produced sparks, and in one instance, even an ignition. The authors conclude that no benefit is gained by the use of low-sparking materials in place of steel hand tools to prevent ignitions. R. C. A. THURSTON



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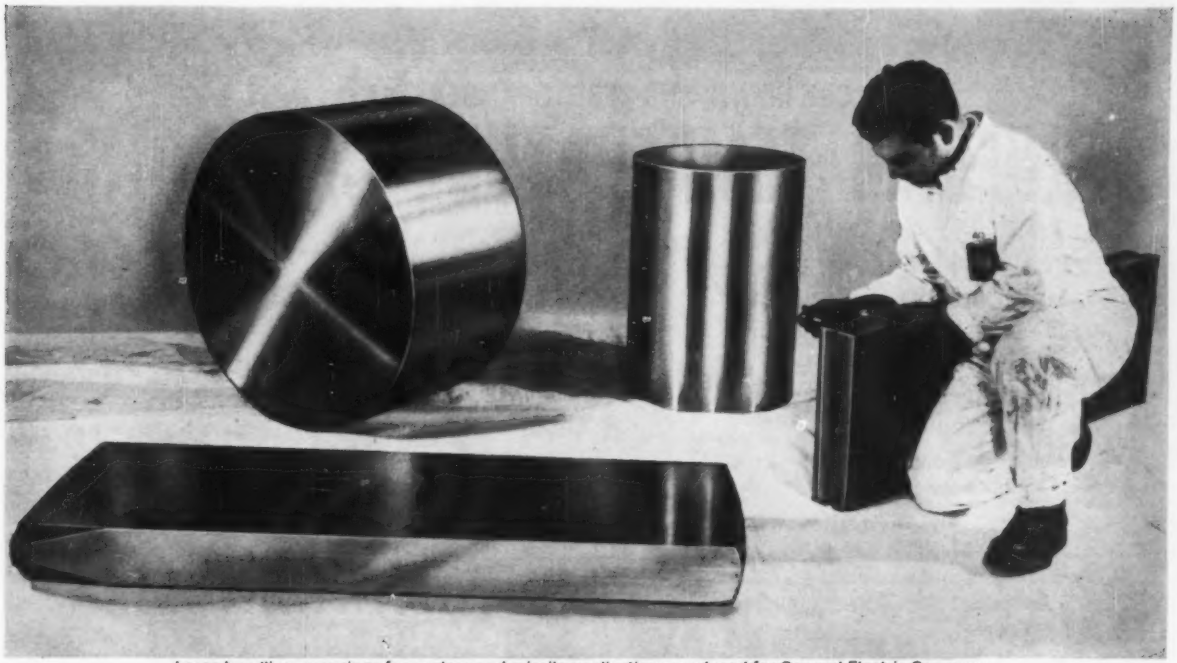
Circle 2417 on Page 48-B



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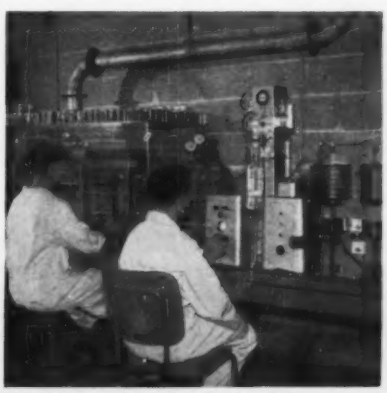

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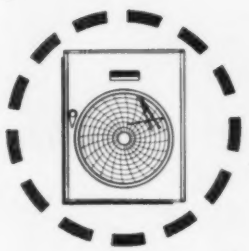

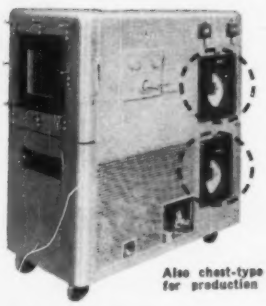

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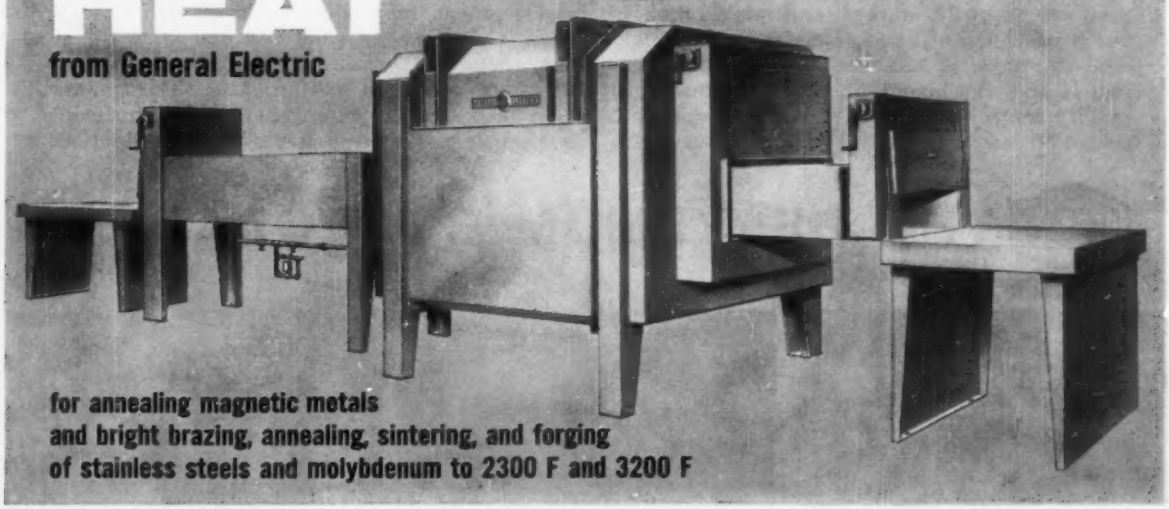
Member: Environmental Equipment Institute

Circle 2419 on Page 48-B

HEAT
from General Electric



for annealing magnetic metals
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NEW Molybdenum Resistor Box Furnaces from General Electric give high temperature operation on a continuous basis with little or no maintenance. Available with cooling chamber (shown above) for temperatures of 2300 F and 3200 F; or without cooling chamber at 3200 F. Furnaces with cooling chamber can be used where atmosphere purities as high as 99.995 percent are required. Molybdenum heating units give rapid heating at high temperatures. Problems of low heating rates, poor heat distribution, and muffle maintenance are eliminated with this years ahead furnace design.

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Circle 50 on Page 48-B

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"M" and "M-10"

Mark any parts while cold, identify them after heat treating regardless of temperatures and oil or water quenchings. Use "M" up to 1600° F., "M-10" up to 2400° F.
WRITE ON LETTERHEAD FOR complete Paintstik information.
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Circle 48 on Page 48-B

ELECTRA HEAT TREATING FURNACES
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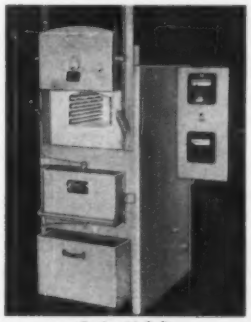
Hardening Range ..... 2000° F and 2300° F
Drawing Range ..... 800° F and 1250° F
Four Standard Models ..... or special design to suit



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Ten models 2000° F and 2300° F range

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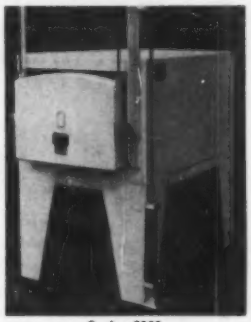

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Circle 47 on Page 48-B

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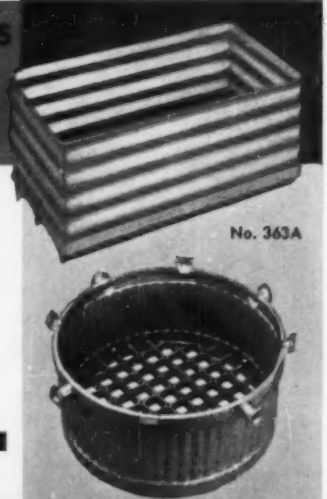

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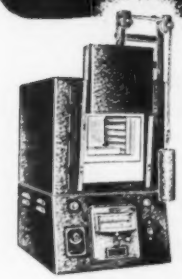

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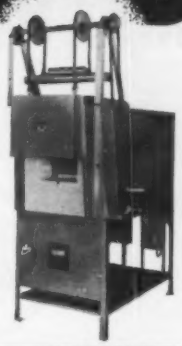

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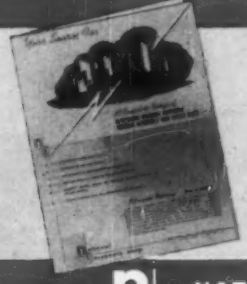

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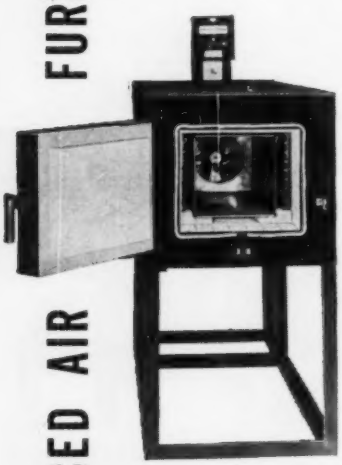
Circle 1 on Page 48-B

LUCIFER FORCED AIR FURNACE



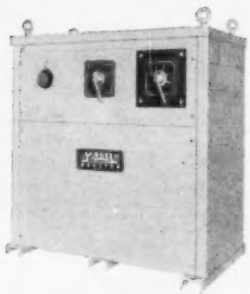
The Lucifer Furnaces, Inc., Series 4055 furnaces are manufactured in 25 standard models with 800° F. or 1250° F. maximum operating temperatures. These furnaces are designed for tempering, drawing, heat treating aluminum, and glass annealing. Each furnace is a complete unit . . . controls included. They are equipped with a large fan and motor to force circulation of air in the working chamber to insure maximum uniformity of temperature.

All electric heat treating furnaces by Lucifer feature • low initial cost • low upkeep • top production performance • minimum replacement downtime. For free engineering advice, parts, or product information . . . write, wire or call . . .

LUCIFER FURNACES, INC.
Neshaminy 7, Penna.
Diamond 3-0411

Circle 26 on Page 48-B

SORGEL
Saturable Reactors



Saturable Reactor with tap changing transformer

Regulate and control electric ovens and furnaces more accurately and efficiently

Any amount of A.C. power from 1 Kva to 3000 Kva, single phase or 3-phase, at any voltage, can be controlled, regulated, and varied in stepless increments, with SORGEL Saturable Reactors.
The control can be a small manually operated hand wheel that can be placed in any desired location, or it can be automatically controlled, regulated and varied by a thermostat or any other instrument or device.
SORGEL reactors are designed to meet your exact requirements. Let us know what your problems and requirements are, and we will submit our recommendations with complete information.

Write for Bulletin 658.

•

Also a complete line of dry-type transformers.

All standard and intermediate ratings, ¼ Kva to 10,000 Kva, 120 to 15,000 volts.

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Sales Engineers in principal cities

Consult the classified section of your telephone directory, under the heading "Transformers," or communicate with our factory.

Sorgel Electric Company

834 W. National Ave., Milwaukee 4, Wis.
Since 1916 devoted to creative engineering and manufacturing craftsmanship

Circle 16 on Page 48-B

GET A BID FROM

HOOVER

SPECIALISTS IN THE FIELD OF
Die Castings
SINCE 1922
Aluminum and Zinc

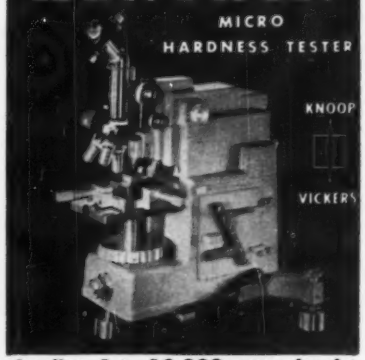
HOOVER

THE HOOVER COMPANY
Die Castings Division
North Canton, Ohio
In Canada—Hamilton, Ontario

Circle 41 on Page 48-B

KENTRON

MICRO HARDNESS TESTER



Applies 1 to 10,000 gram loads

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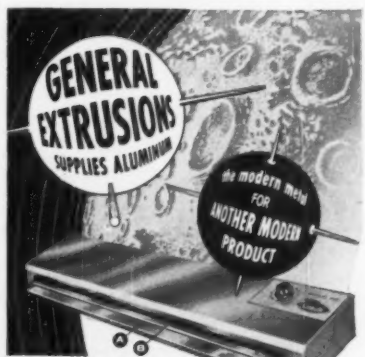
Kent Cliff Laboratories Div.
The Torsion Balance Company
CLIFTON NEW JERSEY

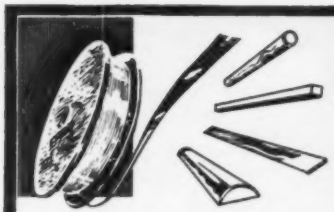
Circle 19 on Page 48-B



This new Super Satellite rotary diazo printer is acclaimed by draftsmen as the fastest white-printer in the low price field. Made by Grico, Inc., of Cuyahoga Falls, Ohio, its feedboard (A) and paper guide (B) are aluminum, extruded, polished and anodized by General Extrusions, Inc.

GENERAL EXTRUSIONS, INC.
4040 Lake Park Road • Youngstown, Ohio
Sales Offices at St. Louis, Pittsburgh, Chicago, Cincinnati, Cleveland and Chattanooga

Circle 2 on Page 48-B



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Beryllium Copper • Bronzes
Other Non-ferrous Alloys
Rounded or square edges.
Available with hot-tinned finish for solderability.
Write for descriptive folder.

LITTLE FALLS ALLOYS
INCORPORATED
193 Caldwell Ave., Paterson 1, N. J.

Circle 40 on Page 48-B

THE NEW
DERMITRON
NON-DESTRUCTIVE COATING THICKNESS TESTER

FAST... ACCURATE NON-DESTRUCTIVE DIRECT-READING

- Instantly measures the thickness of metallic and non-metallic coatings and films
- Based on eddy-current principles
- Enables measurements on small or otherwise inaccessible areas

This portable instrument for both laboratory and production use, gives fast, accurate and direct readings of virtually any coating on any base, including:

- Metal coatings (such as plating) on metal base (magnetic and non-magnetic)
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- Metal films (such as vacuum metalizing) on non-metallic base (plastics, ceramics)

Write for latest bulletins and questionnaire to help solve your thickness testing problems

UNIT PROCESS ASSEMBLIES, INC. UPA

Circle 54 on Page 48-B

revolutionary • low cost
Newage
MICROHARDNESS TESTER

- permits direct, accurate readings corresponding to Vickers within a few seconds
- ideally suited for on-the-job production work
- eliminates a microscope, conversion charts, complicated tables
- for rapid and accurate checking of surface layers, thin sheets, flat springs, instrument parts, wire punches, etc.
- can be obtained in 1 kg or 2 kg loads penetrating as little as .000079" or .00016" respectively

PRICE COMPLETE ONLY $575

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Write, wire or call for full details

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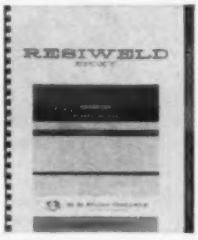
FREE
EPOXY GUIDE



Interested in modernizing your production? Get this handy reference guide on epoxy adhesives, coatings, sealants, and plastic alloys . . . without cost or obligation.

Just write us on your company letterhead and ask for a complimentary copy of Resiweld Book #2.

RESIWELD
H. B. Fuller Co.
ST. PAUL , MINN.

Circle 34 on Page 48-B

RAMCO
modular power spray washers

- MAXIMUM PERFORMANCE
- MAXIMUM ECONOMY

Proof? In this Ramco Bulletin . . . shows how you can create the *right* system for today's . . . and tomorrow's needs. *Send for your copy* NOW! Ask for Bulletin 659-1.

RAMCO EQUIPMENT CORP.
DIV. OF RANDALL MFG. CO., INC.
809 Edgewater Rd. • New York 59, N.Y.

Circle 42 on Page 48-B

LA-CO
Aluminum Soldering Flux
Now . . . Solder Aluminum with ordinary soft solders

- Use 60-40, 50-50, 40-60, 95-5 solders
- No new soldering techniques
- Non-acid . . . Self-cleaning

A major breakthrough in aluminum fabrication. Use ordinary soft solders . . . ordinary irons or torches. Remarkable fluxing action achieves perfect bond of aluminum and solder making possible the fabrication of aluminum to aluminum, copper, steel, stainless steel, galvanized iron, brass, etc.

Write for sample, or engineering help on any fluxing problem.

LA-CO ERAND
LAKE Chemical Co.
3079 W. Carroll Ave., Chicago 12, Ill.

LA-CO
Silver Solder Flux
Greater speed and economy for all silver soldering!

- Packed in tins
- Will not harden
- Non-acid . . . Self-cleaning

For all silver soldering in 1125° to 1700° F. heat range. Dissolves all refractory and non-refractory oxides . . . solder penetrates completely into all areas, for maximum strength without solder waste. Completely acid-free—will not pit or stain metals. Always-ready paste form . . . will not harden or crystallize.

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LA-CO ERAND
LAKE Chemical Co.
3079 W. Carroll Ave., Chicago 12, Ill.

LA-CO
Stainless Steel & Chrome Soldering Flux
Safer . . . Surer . . . Cleaner

- Doesn't stain
- Non-acid
- Self-cleaning

For soldering all stainless steel and chrome, including 300-400 Series, with ordinary soft solders. Requires no pre-cleaning. Acid-free formulation will not pit metals, leaves no stains. No buckling on even light gauge work. In liquid or paste form.

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LAKE Chemical Co.
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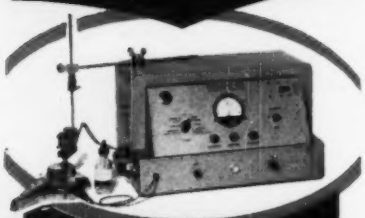
Circle 4 on Page 48-B

TESTING PLATING THICKNESS?

15 Day FREE Trial
Guarantees Satisfaction



KOCOUR ELECTRONIC THICKNESS TESTER MODEL 955

Model 955 determines the thickness of decorative and heavy chromium, silver, tin, cadmium, zinc, brass, copper, nickel, lead, and other metallic deposits on various base metals. 90 - 95% accurate . . . Direct reading . . . simple operation.

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CHICAGO 32, ILLINOIS

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Star Stainless screws have clean—bright—shiny—heads

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CORROSION RESISTANT

Circle 43 on Page 48-B

All that 'Quality' and 'Service' imply are yours with:

PRODUCTS OF TECHNIC RESEARCH for Precious Metal Plating

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Heat resistant 24Kt Acid Bright Gold, extremely low porosity, hard and ductile

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24Kt Acid Bright Gold, tight grain, superior throwing and leveling power

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For semi-conductor plating

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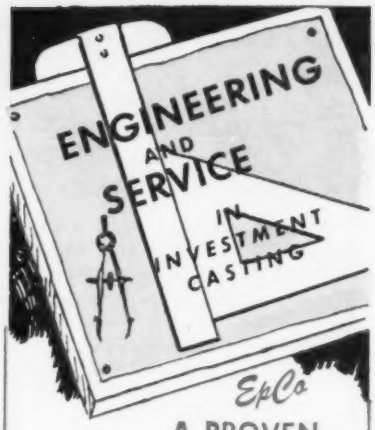

A PROVEN DEPENDABLE SOURCE
FOR BETTER GRADE INVESTMENT CASTINGS IN FERROUS AND NON-FERROUS METALS

INVAR CASTING Special Feature — Nickel content held to 35% minimum — 36% maximum

STAINLESS STEEL PART for milk bottling unit formerly machined from solid stock. Only finish operations required are reaming small dia. of counterbored hole and drilling and tapping for set screw.

ENGINEERED PRECISION CASTING CO.
MORGANVILLE, N. J.

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REVCO
ULTRA-LOW TEMPERATURE CABINETS

for
- Research
- Storage
- Seasoning
- Testing

Seven styles...chest capacities from 1.5 to 6 cu. ft. Uprights up to 22 cu. ft. Temperatures to —140° are controllable within 1°. Immediate delivery.

For FREE folder, "Selecting a Low Temperature Cabinet," write Revco, Dept. MP-100.

Industrial Products Div.
REVCO INC
Deerfield, Michigan
Setting Trends in Refrigeration Since 1938

Circle 12 on Page 48-B

TENSILKUT

Pat. Pend., U.S., Canada

● Now with TENSILKUT, whatever your testing methods or materials, you can have perfect precision machined physical test specimens in less than two minutes.

● TENSILKUT precision machines all foil, film, sheet and plate metals . . . from .0005" foil to .500" plate. Hard .001 stainless steel foil to soft ½" aluminum, soft plastic film 1 mil in thickness or the abrasive glass laminates in .500" plate, are machined with specimen configurations accurate to ± .0005". Machined edges are completely free of cold working or heat distortion and require no hand finishing.

● TENSILKUT table and floor models are available with motors from ½ to 2½ h.p. Write for free brochure.

SIEBURG INDUSTRIES INCORPORATED
Danbury Industrial Park, Danbury, Connecticut
Circle 11 on Page 48-B

HARDNESS TESTING
SHORE SCLEROSCOPE

Pioneer American Standard Since 1907

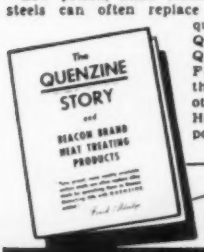
Available in Model C-2 (illustrated), or Model D dial indicating with equivalent Brinell & Rockwell C Hardness Numbers. May be used freehand or mounted on bench clamp.

OVER 40,000 IN USE

SHORE INSTRUMENT & MFG. CO., INC.
90-35M Van Wyck Exp., Jamaica 35, N.Y.
Circle 10 on Page 48-B

FREE
the QUENZINE STORY

Low priced, more readily available carbon steels can often replace alloy steels when quenched in Beacon Quenching Oils with QUENZINE added. For information on this new additive and other Beacon Brand Heat Treating Compounds write to . . .



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INDUSTRIAL OILS, Inc.
3401 W. 140th St., Cleveland 11, Ohio
Circle 29 on Page 48-B

Solve
Inspection
Sorting
Demagnetizing
Problems
with
MAGNETIC ANALYSIS...

MULTI-METHOD EQUIPMENT

Electronic equipment for non-destructive production inspection of steel bars, wire rod, and tubing. Detects mechanical faults and variations in composition and physical properties. Average inspection speed — 120 ft. per minute.

MULTI & SINGLE FREQUENCY EQUIPMENT

Eddy current equipment for non-destructive testing of non-magnetic metal tubing, bars, wire, ⅛" .o 3" dia. at test speeds from 200 to 600 fpm. Multi-frequency unit offers 6 simultaneous inspection methods to indicate surface and subsurface flaws, or variations in mechanical, physical, and metallurgical properties. The single frequency unit offers one inspection method to indicate flaws only.

WIRE ROPE EQUIPMENT

Electronic equipment for inspecting ferro-magnetic wire ropes from 1/32" to 3" diameter. Detects broken, cross-over or missing wires, plus defective welds and deformations at production speeds up to several hundred feet per minute.

COMPARATORS AND METAL TESTERS

Electronic instruments for production sorting of both ferrous and non-ferrous materials and parts for variation in composition, structure and thickness of sheet and plating.

DEMAGNETIZERS

Electrical equipment for rapid and efficient demagnetizing of steel bars and tubing. When used with Magnetic Analysis Multi-Method Equipment, inspection and demagnetizing can be done in a single operation.

MAGNETISM DETECTORS

Inexpensive pocket meters for indicating residual magnetism in ferrous materials and parts.

"THE TEST TELLS"
For Details Write:
MAGNETIC ANALYSIS CORP.
42-44 Twelfth St., Long Island City 1, N. Y.
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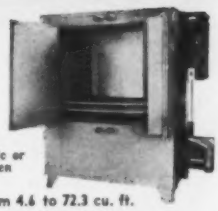
UNIFORM HEAT
throughout the work space

30 STANDARD CABINET MODELS



Model HB Electric or Gas Cabinet Oven

- Work space from 4.6 to 72.3 cu. ft.
- Temp. ranges from 100 to 1250° F.
- Electronic combustion devices for gas models
- Indicating control instrument
- Factory tested

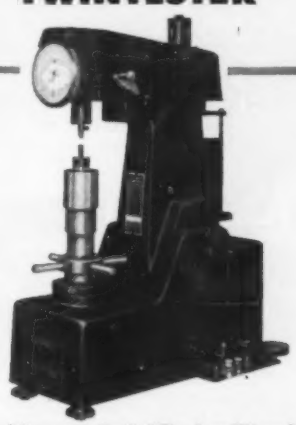
Other ovens from $121.50 up; laboratory, bench, walk-in and custom built models.

Write for details

Specialists in Heat Process Equipment

GRIEVE-HENDRY CO. Inc.
1339 N. Elston Ave. Chicago 22, Ill.
Circle 21 on Page 48-B

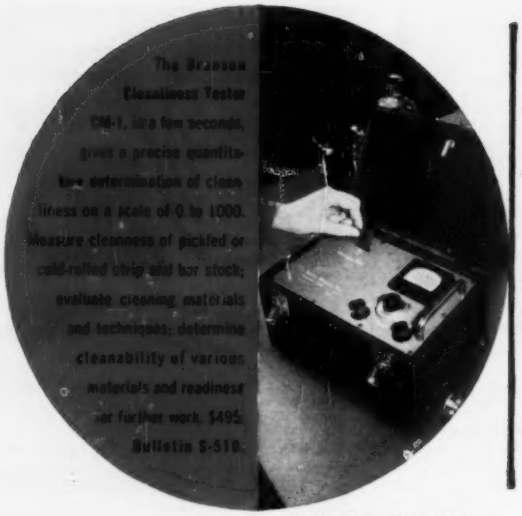
Wilson "Rockwell" TWINTESTER



- Measures both "Rockwell" and "Rockwell" Superficial hardness on B, C, N, T and other scales
- Easy to operate—change from "Rockwell" to "Rockwell" superficial testing in seconds
- Large direct-reading dial with one zero set position for all scales
- Complete equipment includes cowl, ball penetrator for B and T scale, "Rockwell" test blocks, anvils, dust cover, and protective sleeve set
- Complete line of accessories available

Write to Dept. DU. Ask for Bulletin TT-59

WILSON "ROCKWELL" HARDNESS TESTERS
Wilson Mechanical Instrument Division
American Chain & Cable Company, Inc.
230-F Park Avenue, New York 17, N.Y.
ACCO
Circle 45 on Page 48-B



DO YOU KNOW...

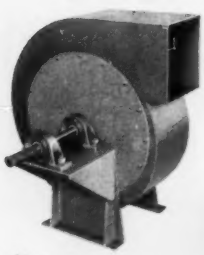
HOW CLEAN IS CLEAN?

BRANSON ULTRASONIC CORPORATION
6 Brown House Rd., Stamford, Conn.

Circle 33 on Page 48-B

Low maintenance cost on

GARDEN CITY FANS



Special problem?
Ask us about Garden City's Custom-Built Fans

Write for bulletins on

RF Thermal-Aire Fans
High temperature fans for recirculation, exhaust, induced draft. Handle hot air or gases to 2000°F. Bulletin RF 589-H.

RF Industrial Fans
For ventilating, exhausting corrosive fumes and vapors, for dust control. For material handling. Bul'etin 589-1.

REPRESENTATIVES IN LEADING CITIES

GARDEN CITY FAN & BLOWER Co.
ESTABLISHED 1879

813 North Eighth St., Niles, Michigan

Circle 57 on Page 48-B

TEST
HIGH-LOW
ELONGATION WIRE MATERIALS

VERSATILITY AND ECONOMY are key features of the Scott Model CRE Electronic Tester. You get ultra-high accuracy of inertialess electronic weighing . . . plus effortless, error-free, push-button testing of wire products *at amazingly low cost!* Stress-strain information "picturized" on strip chart. Ample magnification for detailed analyses of wire, insulation sheath, cable components. Interchangeable test capacities to 1000 lbs. For facts on Model CRE Tester, write **Scott Testers, Inc., 187 Blackstone St., Prov., R. I. Tel: DExter 1-5650 (Area Code 401).**

SCOTT TESTERS
THE SURE TEST... SCOTT!

Circle 58 on Page 48-B

How to Cut Pot Costs:

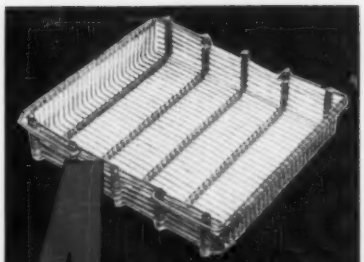
Buy low-cost Eclipse pressed (not welded) steel pots . . . and replace them on a regular schedule.

1 Lower initial cost
2 Elimination of failures
3 Faster, more even heating
4 Quantity discounts earned on your total purchases in any 12 month period.

Guaranteed free from defects. Write:
Eclipse Fuel Engineering Company
Industrial Combustion Division
1127 Buchanan St., Rockford, Ill.

Eclipse PRESSED STEEL POTS

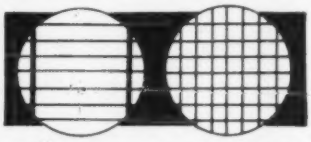
Circle 27 on Page 48-B



4 MORE REASONS YOU SHOULD TRY...

bixco
FABRICATED
HEAT-TREAT BASKETS

1 MORE OPEN AREA
Our unique looped wire liner (with slotted openings) affords 30% to 100% greater open area than conventional liners. Faster heats, greater circulation of atmospheres and more uniform quenches are a direct result.



bixco BUILT-IN Looped Wire Liner — Conventional Liner

2 LESS WEIGHT
In the Economy 6 Series with built-in liner and round rod framing, total basket weight is kept to an absolute minimum without sacrificing high strength.

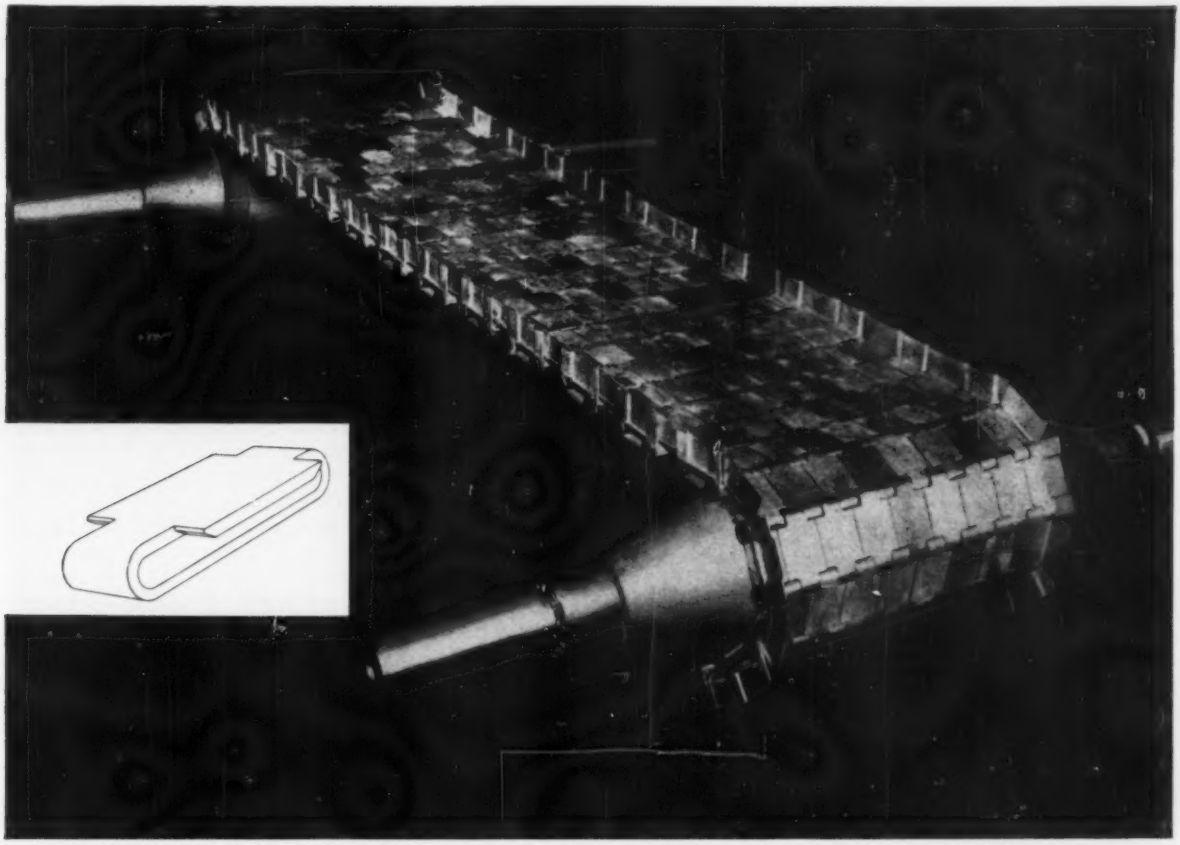
3 TRUE ECONOMY
Our many exclusive features bring basket maintenance and furnace operating costs DOWN. Bixco baskets perform better because they are made better.

4 SPACE AGE ENGINEERING
Meeting the demands for better baskets is a Bix Company specialty. Besides fabricating in all standard metals we also produce baskets of Molybdenum. Special designs and applications are available on request.

For complete information write:

bix COMPANY
FAIRGROUNDS ROAD
WELLINGTON, OHIO

Circle 25 on Page 48-B



Design of Cast Link—Simplicity aids in reducing in-furnace stresses. HT cast alloy carries the load with minimum creep.

Cast to last inside continuous furnace

Alloy containing 35% Nickel provides 1000-hour rupture strengths of 7000 psi

In this furnace belt, long life and the maintenance of design dimensions were paramount needs.

The belt moves 20 to 30 pounds of work per square foot through a continuous furnace installed at the Cleveland plant of The National Screw & Manufacturing Company. Temperatures range from 1550°F to 1700°F. Atmospheres are controlled and may be either an atmosphere of endothermic generator gas or endothermic gas enriched with methane. Work enters cold and subjects the belt to considerable thermal shock.

High nickel cast alloy satisfies both design requirements

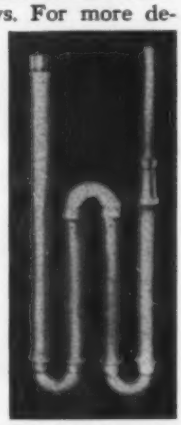
Surface Combustion Division of Midland-Ross Corporation uses castings made of A.C.I. Type HT alloy to provide the necessary properties. This is a 35% Nickel, 15% chromium material specially developed for high temperature service.

It is well suited for carburizing furnace fixtures and containers. In sulfur-free atmospheres HT alloy retains useful strength up to 2100° in oxidizing atmospheres. At 1600°F, its 1000-hour rupture strength averages 7000 psi. And it has good machining and welding properties.

In this equipment, the designer used the alloy for the belt link, supporting roller and drive- and idler-drum castings. What's more, this alloy is so versatile, he was also able to use it for the twelve W-type radiant tubes supplying heat. Here, where the alloy also has to withstand oxidizing combustion gas at high temperature, its high nickel content helps minimize scaling.

Other heat- and corrosion-resisting casting alloys serve other needs

A wide range of properties can be obtained in today's heat- and corrosion-resisting alloys. For more detailed information on these and on the HT alloy described above, write for the Inco booklet, "Heat- and Corrosion-Resistant Castings...Their Engineering Properties and Applications."



Radiant tube—Unit is formed by welding centrifugal-cast straight sections to static-cast return bends.

THE INTERNATIONAL NICKEL COMPANY, INC.
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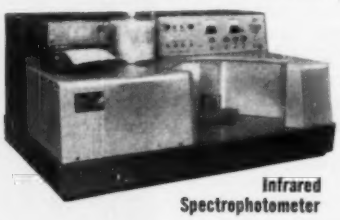

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Defects in Steel

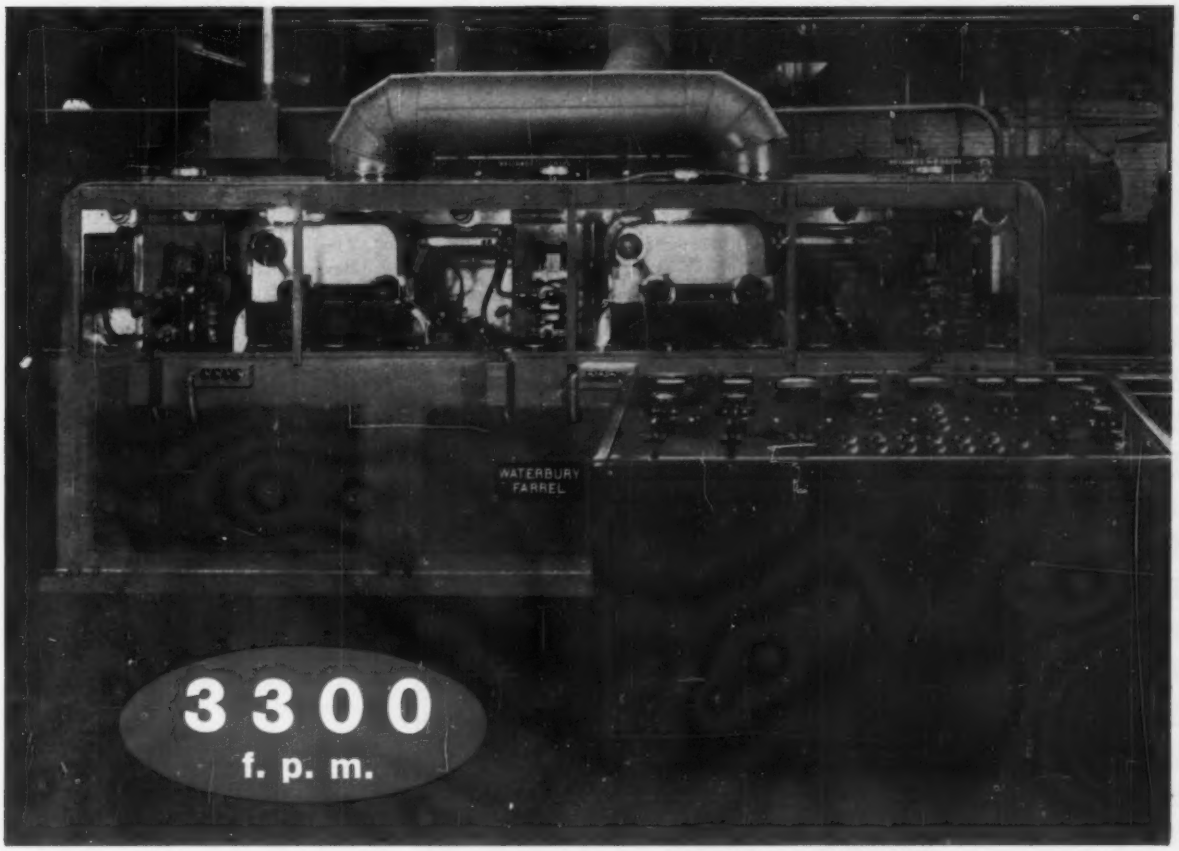
Digest of "A Radio-Active Tracer Study of Steel Defects", by T. W. Crosta. Paper presented at A.I.M.E. National Openhearth Conference, 1958.

CRACKS (OR SPLITS) parallel to the rolling direction are the most common defects in killed steel billets which have been upset preparatory to being forged or extruded. In fact, upsetting is such a severe test of surface quality that it is sometimes used for inspection. Because surface defects are of critical importance in many applications, their origin was investigated.

Many splits or cracks in upset billets originate from seams produced by rolling, but the author found that some occur in stock comparatively free of the common type of seams. Furthermore, splits were less frequent in billets rolled from surface-conditioned blooms than in billets rolled directly from ingots. The preliminary study indicated that the incidence of cracks was relatively independent of heating procedures and upset forging practices. No correlation was found between the frequency of splits in C 1012 killed steel and such steelmaking variables as chemical composition, pouring temperature, or rolling temperature.

In the course of the investigation, tensile specimens taken from forgings transverse to the direction of rolling were pulled to fracture. Usually, a film of nonmetallic material was found at the base of the split defect. Similarly, transverse specimens of apparently sound metal near the surface of billets occasionally disclosed thin, grey, lenticular nonmetallics just below or tangent to the surface. These defects were about 1⅛ in. long and ⅛ in. deep in samples representing a 10 to 1 elongation of the ingot. Spectrographic analyses of some of the small particles indicated the composition was 55% SiO_2, 1.4% Al_2O_3, 1.0% MnO and 33% Fe. The gray scum appeared to consist principally of alumina and silica.

There appeared to be a direct correlation between the incidence of splits caused by upsetting and peculiarities noticed on the surface of billets. This surface condition was called "slag" because nonmetallics were sometimes visible on



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Circle 2413 on Page 48-B

Defects in Steel . . .

scarfed billets. The presence of such material causes a flash of white light in the cutting flame during scarfing and sometimes leaves a discontinuity on the scarfed surface. The visible slag defects were brown in color; they occurred in small or large patches, and were not characteristic of particular positions in the heat or ingot. Plant records indicated that increasing the thickness of the refractory facing or patching on the hot top increased the trouble in upsetting.

All of these observations suggested that the silicious facing used on the hot tops was the source of the "slag" found at or near the surface of killed steel billets. This possibility was checked by a series of experiments. First, some of the material used for facing (94% SiO_2 plus an organic binder) was added to a mold during pouring. Billets from this ingot exhibited heavier concentrations of "slag", closely resembling the defect under study, than billets from an untreated ingot.

Then experiments were run on C 1012 fine-grained steel with lanthanum oxide as a tracer because it has a suitable activity and half-life. Further, it would not be reduced by the deoxidizers present in the steel. The lanthanum oxide was mixed intimately with the various refractory materials of interest. It was assumed that the radioactive lanthanum would be eroded with the refractory, and could be used as a tracer to detect refractory material in ingots and billets. The experiments, with various hot top and pouring practices, were conducted on 100-ton heats. Closed-bottom, hot topped 26½ in. square big-end-up molds and an open, big-end-down 26 × 30-in. mold were used for the experiments. The effects of experimental variables were evaluated by scanning the ingots for radioactivity with both scintillometers and Geiger counters. The billets were also examined for surface and subsurface defects.

The experimental investigations led to the following conclusions:

1. Refractory material washed from slurries used to face top linings seems to concentrate at both top and bottom of the ingot. Refractory from the top-top ring area is usually confined to the upper part of the ingot.

2. Coating hot tops with damp slurries resulted in nonmetallic material in the steel. The appearance and pattern of occurrence was similar to the slag-type defect.

3. In many instances, seams and scabs on billets were directly associated with radioactive nonmetallic material in the steel. Sometimes, the defects were not associated with the radioactive material deliberately added to the pouring system.

4. Billets from ingots made in molds containing nonmetallics on the stool (or as-stool coatings) required complete surface conditioning to remove scabs and seams. Less billet conditioning was necessary when the radioactive material was used as a hot top facing.

5. Exogenous inclusions derived from hot top and stool coatings were confined to the surface layers of the steel. In 8½ in. square billets they existed to depths of 3/16 in. below the surface. Some of the defects

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Defects in Steel . . .

are removed by scaling when an ingot is heated for rolling.

6. In completely dried hot top linings, pouring with a spraying stream increases the severity of contamination of the steel. Surface quality can be improved by using strong, high-temperature cements for facing the lining of hot tops.

F. W. BOULGER

Ductility of Coatings

Digest of "The Ductility of Plated Coatings", by H. J. Read and T. J. Whalen. Paper presented at the Golden Jubilee Convention, American Electroplaters' Society, Detroit, June 1959.

IN RECENT YEARS preplated metals have been increasingly used in many manufacturing operations that involve deformation. Since the coating must withstand stresses comparable to those of the base metal, it is not surprising that many instances of stress-corrosion cracking have been reported on resulting products.

In an attempt to devise an improved testing method to measure tensile strength and ductility of thin coatings, the authors have substituted a hydraulic bulge test for the Erichsen cup test.

Test methods followed the principles of Jovignot, in which thin sheet specimens are cupped by applying controlled hydraulic pressure over a uniform area. Figure 1 shows a schematic of the test method. The specimen is positioned between two platens, and oil, under pressure, is introduced through the lower platen. The assembly is held together with a small hydraulic jack. Rates of pressure application and maximum pressure were controlled with a suitable piston and gear drive. Stress values were related to the vertical movement of the specimen, as measured with an optical micrometer.

Some specimens were prepared by dissolving away the base metal, or by mechanically stripping the deposit. Other samples were tested on thin substrates. Results showed that properties of deposits could be determined by first testing the base metal, then the composite. The difference in strength was assumed to be that of the film. However, this relationship holds only if the substrate is thinner than the deposit.

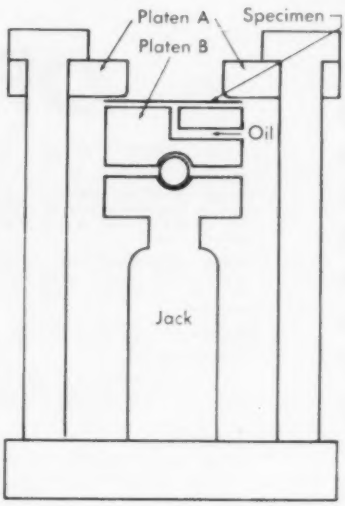
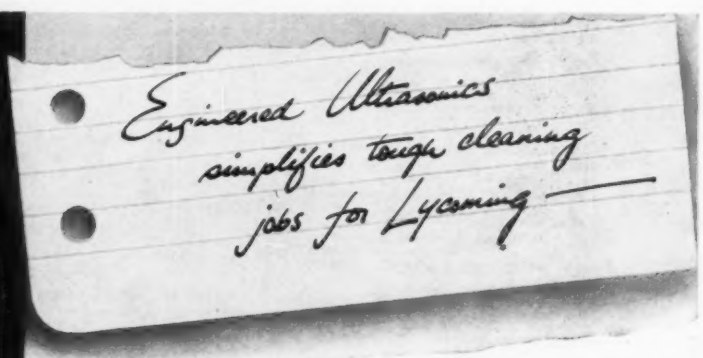


Fig. 1 — Drawing of Testing Setup



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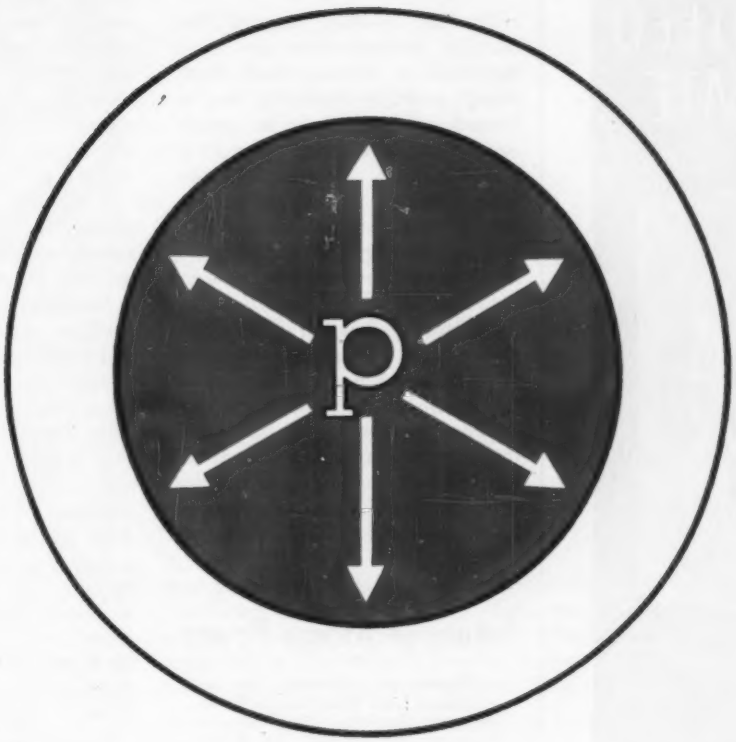

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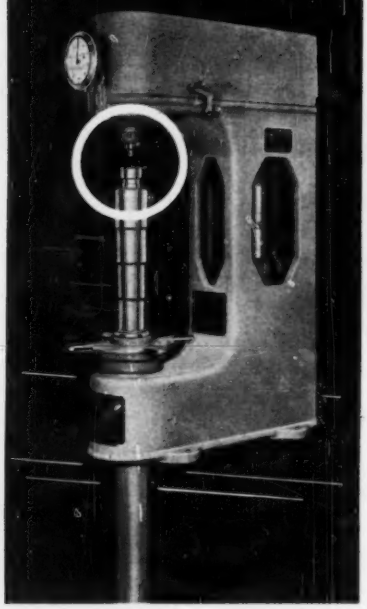

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Missile-Age Accuracy

Circle 2470 on Page 48-B

Ductility of Coatings . . .

Principal findings showed that ductility measurements on thick specimens in ordinary tensile tests, though useful in evaluating electroformed products, have no significance for evaluating protective plated coatings. Data on thick specimens cannot be extrapolated to thin coatings because relationships between ductility and thickness are rarely even approximately linear.

Sample data and discussions by the authors lead to the general conclusions that ductility measurements of plated coatings are influenced by the nature of the base metal, the deposit thickness, and base-metal thickness on composite tests. Strain rate, pinholes and aging of samples appear to have little or no effects on measurements. J. L. WYATT

Future of Atomic Power

Digest of "Energy as an Ultimate Raw Material, or Problems of Burning the Sea and Burning the Rocks", by Alvin M. Weinberg. An address presented before the American Physical Society, April 10, 1959.

ALVIN M. WEINBERG, who has been actively engaged with studies in the realm of physics at Oak Ridge for nearly 20 years, and who is at present director of Oak Ridge National Laboratories and president of the American Nuclear Society, is well informed about mankind's energy requirements in the fairly near future. He says early in his talk that "the search for new primary energy sources – and for new energy converters – has become an enormous scientific frontier in which physicists naturally are taking the leading role" –and, he might have added "in company with chemists, metallurgists and engineers".

He cites evidence to show that the present population of the earth, 2.5 billion souls, will reach an "asymptotic" number of 7 billion in a few centuries. However, the per capita demand for energy will increase much more; at present it is the equivalent of 4 billions of tons of coal a year; the asymptotic demand will reach 70 billion. The latter rate would exhaust the present reserves of fossil fuels in 35 years! Eventually mankind will have to make do with only four basic raw materials: The sea, the rocks (of average composition since true ores will have been exhausted), the air, and the sun. (If we equate the sun to fire, these are essentially Aristotle's four elements!) The question really is not *whether* we shall reach this state – it is merely *when* we shall reach it.

Eventually, therefore, mankind's energy will come from three major sources – sunlight, energy converters, and primary nuclear sources.

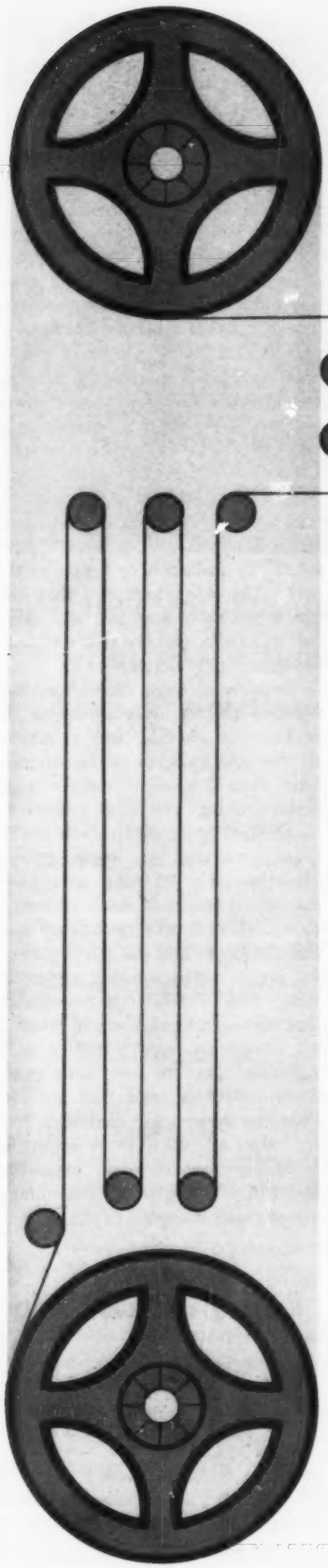
Sunlight – While it is certain that sunlight will always provide food and forest products, and eventually a large fraction of our needs for space heating, Weinberg quotes another author to dispose of the idea that large amounts of portable energy can be so derived: "The direct collection of solar energy on a vast scale by myriads of tracking mirrors, thermocouples, or other devices, its overnight storage, its conversion to transportable electricity, and its delivery at low cost from Arizona to Pittsburgh or from the Sahara to the Midlands appear remote in the light of what we know today."

Energy converters include silicon batteries and thermo-electric devices (thermocouples in series) which convert heat directly into electricity. They are simple but – as far as is now known – their efficiencies are quite low.

Nuclear energy can be derived from two sources, heavy hydrogen (deuterium) from the sea, and uranium and thorium from the rocks. Either of these sources can produce power at the asymptotic rate for more than the anticipated future life of our solar system. "*Either* sea-burning or rock-burning could *in principle* be made the primary energy sources for the rest of mankind's history, at a cost within striking distance of today's power" derived mainly from fossil fuels.

Fusion – An important advantage of the fusion of hydrogen into helium is that its radioactive wastes ought to be much less troublesome than those from fission reactors, but fusion of "plasma" has yet to be demonstrated on a self-perpetuating basis. The extraordinary difficulties may be judged from the necessary pressure: 60 atmospheres – usually held by stout steel walls but in this equipment by magnetic lines of force.

Fission is of course now operating



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Atomic Power . . .

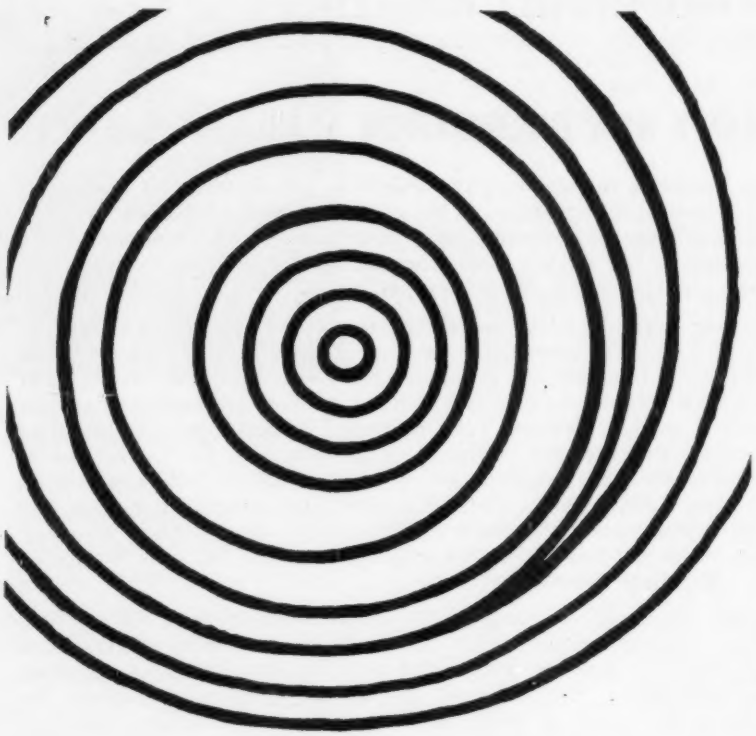
in power-producing reactors of two general types: *(a)* Byproducts heat from natural uranium reactors primarily operated for the manufacture of plutonium for explosives, and *(b)* reactors whose fuel is enriched with the scarce uranium isotope 235. "In the asymptotic state – and to extract the uranium and thorium from granite at low cost – we must burn up much more than the U^{235}; we must breed fissionable Pu^{239} from the U^{238} or convert Th^{232} to U^{233}."

The first mentioned is best done by fast neutrons, and the engineering problem of power production resolves into one of getting a lot of heat out of a small volume. Experimental reactors using this principal now produce power, but at a high cost. "At present the major effort in the fast breeder development is aimed at reducing fuel cycle costs either by increasing fuel burnup (through the use of better alloys or fluid fuels or oxide fuels), or by simplifying the chemical reprocessing by pyrometallurgical methods."

Mr. Weinberg apparently holds more hope for the reactor wherein surplus neutrons from uranium fission are caught by thorium atoms and thereby breed fissionable U^{233}. This can be done by thermal neutrons, and the moderator can be the deuterium in heavy water. In principle, the fuel can be a liquid solution and it can be constantly purified. Reactors of this sort have been operated at Oak Ridge wherein a zirconium sphere contains a solution of UO_2SO_4 in D_2O; neutrons leaking out are absorbed in a surrounding slurry of ThO_2 and D_2O contained in a stainless steel pressure vessel. Further advantages of such a system are that the fuel can be burned to any extent desirable and it is not "poisoned" by radiation or fission products. The disadvantage is that the fuel is intensely corrosive and difficult to handle, and the entire system becomes highly radioactive.

"In spite of these difficulties, the aqueous thermal breeder seems to be basically feasible, and to satisfy all the requirements of an asymptotic fission energy source – high power rating, low fuel inventory, simple fuel cycle, and the ability to breed – centered in great power plants possibly 20 times as big as the largest coal-fired steam plants of today. But it will be a long and difficult job to iron out the engineering bugs – perhaps taking a generation. But I consider it remarkable that we see at hand a way of starting our asymptotic energy system with materials that are even now practically available, and that we can keep the system supplied with fuel for essentially all time by means of a mining operation only somewhat larger than the present coal mining operation of the world!"

E.E.T.



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Circle 2471 on Page 48-B

Rolling Titanium Strip

Digest of "The Rolling of Thin Titanium Strip", by R. G. Wilcox and P. W. Whitton, *Journal* of Institute of Metals, Vol. 88, 1959-60, p. 200-204.

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Rolling Titanium . . .

too small to justify the cost of special rolling mills. But by reducing friction between rolls and strip, it is often possible to roll high-strength material to thin gages on existing equipment which was designed for softer, heavier-gage sheet.

The authors of this paper show that proper lubricants can reduce roll loads up to 60% for thin, hard titanium strip. They applied rolling theory to compute coefficient of friction, which varied from 0.3 to 0.18 for the lubricants tested. Surface preparation of the strip has only a secondary effect on friction.

Tests were conducted on a two-high mill having 8¼-in. diameter rolls which were polished to a 2 to 3 micro-in. finish. Roll separating force (or rolling load), reduction in strip thickness, and strip width were measured during tests. Rolling tests were made on commercially pure titanium strips 0.037 in. thick; five surface treatments and five lubricants were tested. Surface treatments were (*a*) bare (as-pickled), (*b*) oxidized, (*c*) anodized, (*d*) phosphated, and (e) cyanide-nitrided. Lubricants (see Fig. 1) were (1) straight mineral oil, (2) mineral oil with E. P. additives, (3) potassium palm oil soap, (4) anhydrous lanolin, and (5) Fluorolube grease (chlorofluorinated hydrocarbons containing graphite).

The straight mineral oil was used as a standard. While lanolin and Fluorolube grease are not suitable for industrial application at present, they were included in an effort to determine how much load reduction was possible.

The Cook-Larke method established first-pass load-reduction curves for each combination of surface and lubricant. These curves were used to find the loads which would be developed when making 10% reductions with 8¼-in. diameter rolls. The results are shown in Fig. 1. Obviously, lubricant No. 5 does much more to reduce roll load than the other lubricants tested. Surface condition has little effect, as shown by the nearly horizontal position of the curves.

Actual values of coefficient of friction were found by applying the methods of Bland and Ford, and Sims. Computations included allow-

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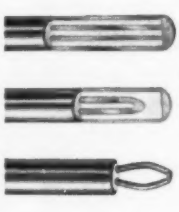

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ances for the elastic contribution of the rolled strip. This factor, which is often neglected, reached values as high as 15% of the total load. The friction coefficient for lubricant No. 5 ranged from 0.03 to 0.06, compared with values from 0.15 to 0.19 for the other lubricants.

Except for lubricant No. 5, the friction values for rolling titanium are higher than those which have been found for mild steel, copper, brass and other metals. This high

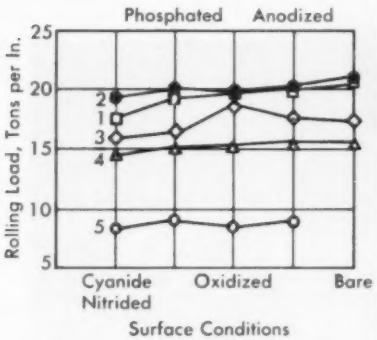

Fig. 1 — Comparison of Loads for a 10% Reduction of Titanium Strip Given Various Surface Treatments and Rolled With Different Lubricants

friction combined with high strength results in greater rolling loads. But by using a suitable lubricant, loads often can be reduced to a point which will permit rolling thin, hard titanium strip on a conventional rolling mill.

The description of general procedure and the list of references in this paper make it valuable to anyone planning to conduct cold rolling tests on high strength materials.

B. L. SHAKELY

Fatigue of Bearing Steel

Digest of "Effect of Hardness, Surface Finish, and Grain Size on Rolling Contact Fatigue Life of M-50 Bearing Steel", by R. A. Baughman. A.S.M.E. Paper No. 59-Lub-11 presented at the A.S.M.E.-A.S.L.E. Lubrication Conference, October 1959, New York.

A ROLLING CONTACT fatigue rig was used to study the effect of hardness, surface finish and grain size upon the fatigue life of M-50 tool-steel at room temperature. Cylindrical specimens 3 in. long and ⅜ in.

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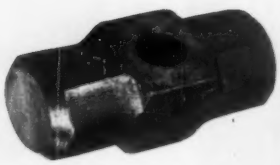

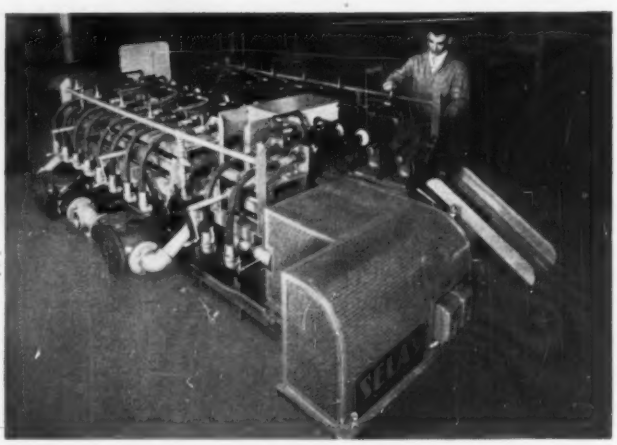

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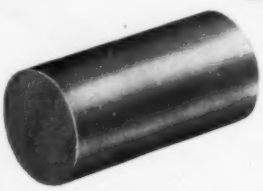

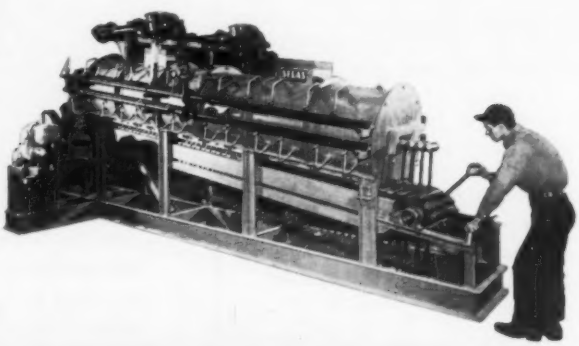

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Bearing Steels . . .

in diameter were tested in rolling contact with contoured rollers. In each test, rollers were processed to match the hardness, surface finish and grain size of the specimens.

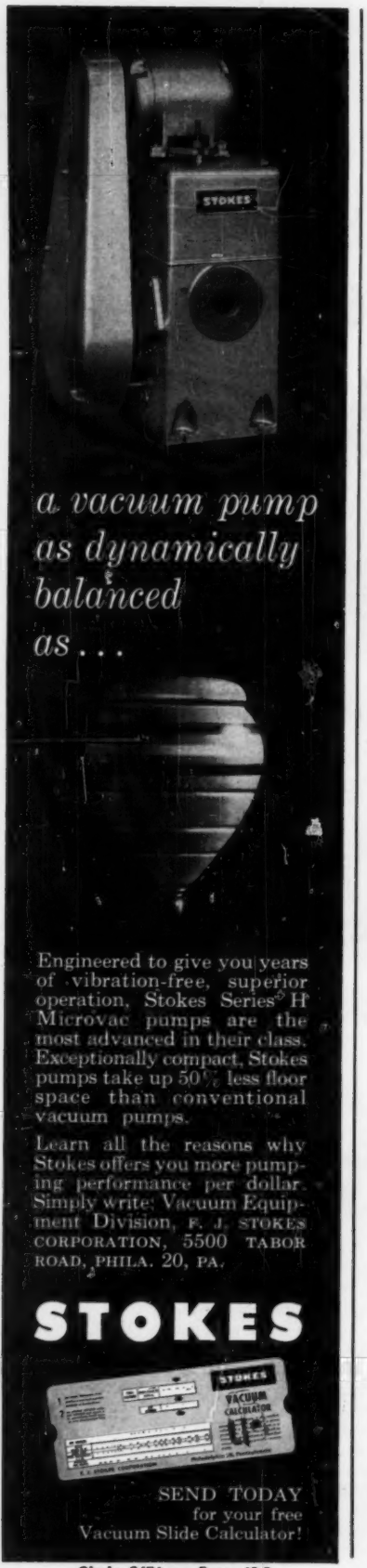
Hardnesses from Rockwell C-52 to 64 were obtained by double tempering at various temperatures after hardening from 2200° F. Variations in grain size were produced by increasing times at the austenitizing temperature. Surface finish was varied using wheels of different grades to finish grind test specimens and rollers.

Rolling contact tests were run at 30,000 cycles of stress application per minute using Mil-L-7808 lubricant at room temperature. Four tests were run for each combination of hardness, grain size and surface finish at each stress level. Tests were run at five stress levels from 645,000 to 745,000 psi. maximum surface compressive stress.

The results of various stress levels were combined for statistical analysis by interpolation of B_{10} lives* assuming a linear variation between stresses. Original and adjusted results were then subjected to an extensive statistical analysis in an effort to develop an equation relating fatigue life in rolling contact to hardness, grain size, surface finish and stress level. The analysis of variance showed a confidence level of almost 10% for the B_{10} equation so derived. A "modified B_{10} fatigue life" equation for 700,000 psi. maximum compressve stress was also developed, and the relationship of hardness, grain size and surface finish calculated from this equation was compared to the original data.

The data show that the B_{50} life depended mainly upon hardness, the best life obtained at high hardness. The B_{10} life depended upon the interaction of surface finish and grain size with hardness. Above Rockwell

*B_{10} and B_{50} lives of a collection of tests were the lives up to which 10% and 50% of tests in a population will have failed.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C-54, B_{10} life increased with hardness to a maximum and then decreased. The statistical analysis indicated that the optimum hardness decreased as A.S.T.M. grain size number and rms. surface roughness increased. The B_{10} life was higher for coarser grain sizes and smoother finishes, especially at higher hardness levels. W. E. LITTMANN

Chromizing in a Vacuum

Digest of "Chromizing in a Vacuum", by Frantisek Princ and Václav Navara, *Czech Heavy Industry*, July 1959, p. 20-27.

CHROMIZING is a process which may be defined as the impregnation of the surface of an iron or steel component by metallic chromium or the diffusion of metallic chromium into an iron or steel surface. This imparts wear and corrosion resistance to the surfaces treated. Several chromizing processes are in use commercially. They differ only in the manner by which the chromium atoms are brought to the surface and in the manner by which the chromium atoms are built into the surface. These methods can be broken down into two categories: (a) direct chromizing which uses pure chromium, and (b) indirect compound, generally a halide.

Chromizing in a vacuum, the process considered in this article, is a direct process. The compounds to be chromized are pickled and degreased, and placed in a retort where they are embedded in pure chromium powder. The retort is evacuated and placed in a vertical furnace at 1050° C. (1920° F.) for 8 to 10 hr. It is then transferred to a cooling chamber and cooled by a water spray. Finally, the retort is emptied and the cycle is repeated. The chromized layer is inspected by nondestructive methods such as an induction thickness meter.

This chromizing process is based on the behavior of metallic vapor at low pressures, and on the fact that chromium has a higher vapor pressure than iron at all temperatures. Theory may be summed up very briefly. During chromizing in a vacuum, two processes occur simultaneously; chromium deposits on iron and iron deposits on chromium. The iron deposit on the chromium does not hinder the rate of chromium deposition. If anything, it accelerates it since it increases the vapor pressure in the retort. The two processes continue until equilibrium conditions are reached. When this condition is obtained, the chromium content of the chromized layer on the iron is approximately equal to the iron content of the surface of the chromium.

There are four main factors influencing this process. They are the chemical composition of the steel, the residual gases in the retort, the temperature differences in the retort, and the percentage chromium in the chromium compound. Each of these factors has a different effect on the process.

Carbon is a deleterious element because it forms carbides which hinder the diffusion of chromium into the surface. Furthermore, it reduces the thickness of the chromized layer. All other elements may be divided into two groups: Those which open the loop decrease the diffusion rate, and those which close the loop increase it. Sulphur and phosphorus are also detrimental because they react with hydrogen at higher temperatures, and are transferred to the chromium surface making the process ineffective. In addition, they reduce the corrosion resistance of the chromized steel.

The residual gases, oxygen and nitrogen, are harmful because they form oxides and nitrides which impede diffusion. Hydrogen is considered detrimental because it decarburizes the surface, and the freed carbon forms carbides which impede the diffusion process.

The temperature differences in the retort cause a flow of gases from the hotter to the cooler portions. This results in the condensation of some chromium on the cooler surface. This metal is thus lost to the process.

The percentage of chromium in the chromium compound determines the maximum chromium content in the surface of the component being processed. If a chromium compound (ferrochromium, for example) is used, it should contain more than 60% chromium.

At present this process can be used only for relatively small components because of the dimensional limits of the equipment.

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Rubber tin—A tin compound that stretches like rubber and can be vulcanized has been developed by the Army. Tin is substituted for carbon, the usual base of rubber. The new polymer, alkyl tin methacrylate, is a "stretchable" high-temperature material with greater resistance to chemical fuel than conventional rubber. This may lead to a series of carbon-replacement materials similar to boron chemical fuels.

New tinplate that is lighter, stronger and thinner than any ever made is being researched by major steel producers. It shows great promise and is expected to offer important economic advantages to canners and other tin plate users, for shipping and product protection. No change in tin content of the new plate is indicated.

Nonspattering flux is the result of experiments by Tin Research Institute. The new soldering process uses polyethylene glycol instead of acidified water as a vehicle for acid fluxes. It has a low boiling point—flux won't spatter when it contacts molten solder or soldering bit. Spreads smoothly over large area. Won't rust or corrode; residue washes off easily. Low volatility prevents evaporation; high flashpoint eliminates fire risk. No unpleasant odors or harmful fumes.

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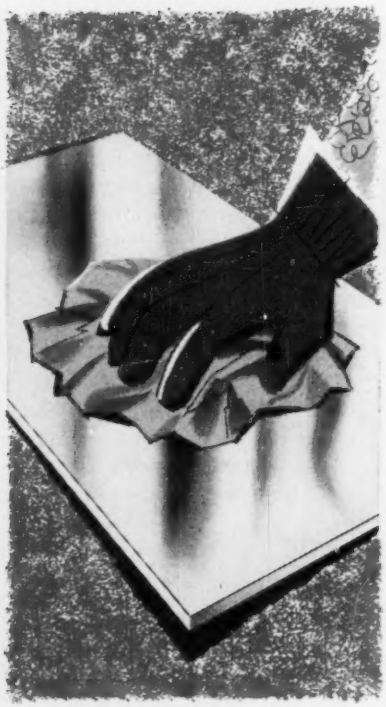

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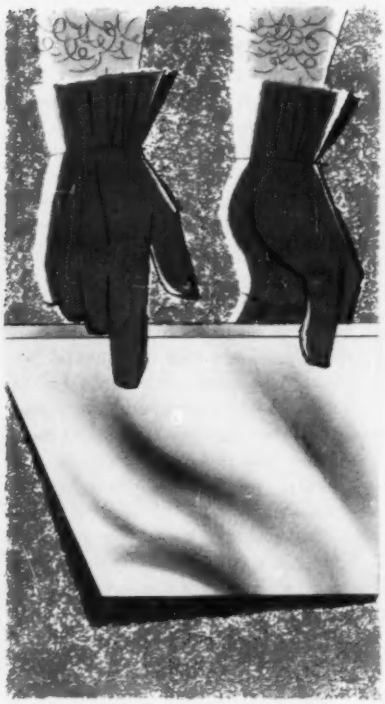

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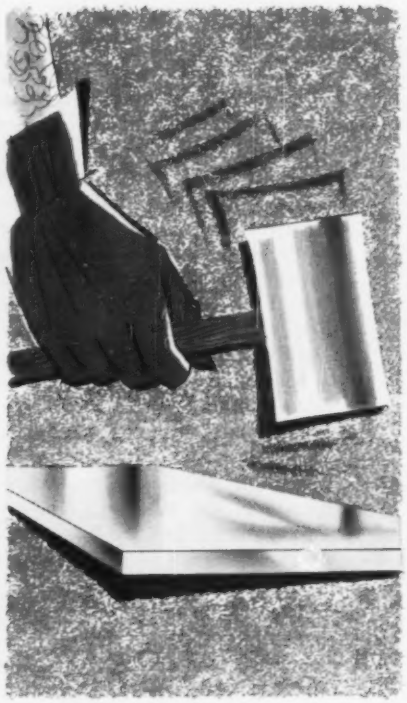

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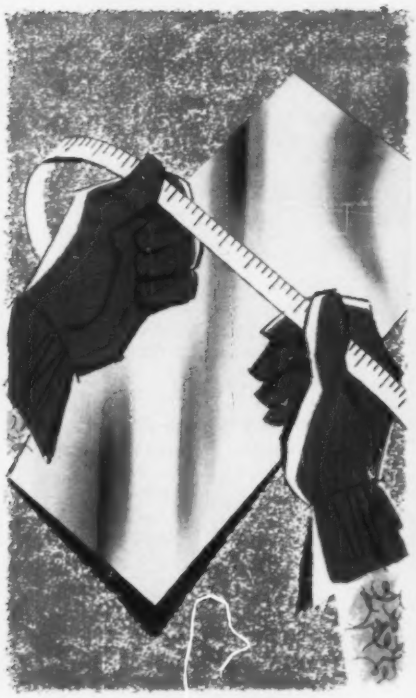

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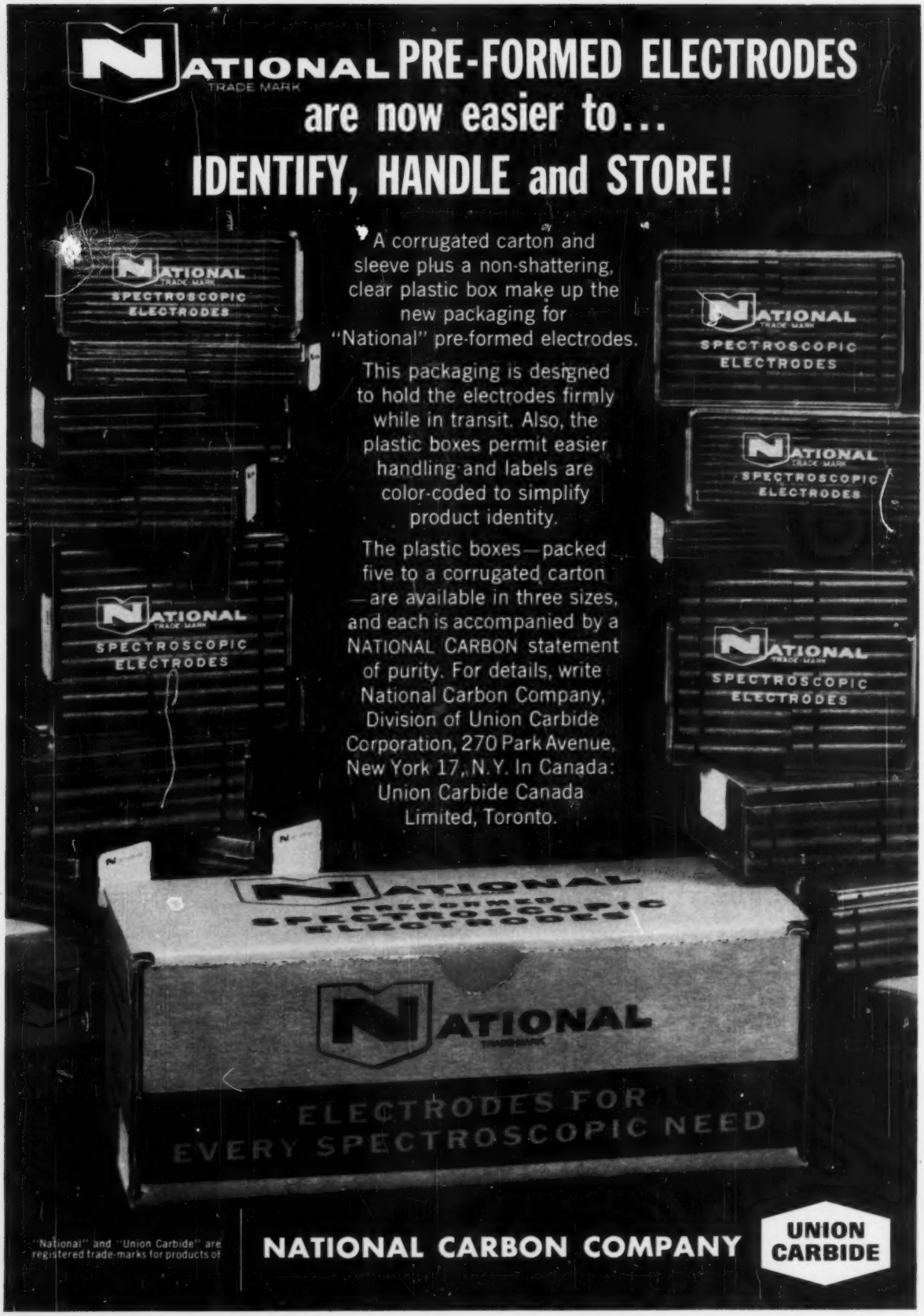

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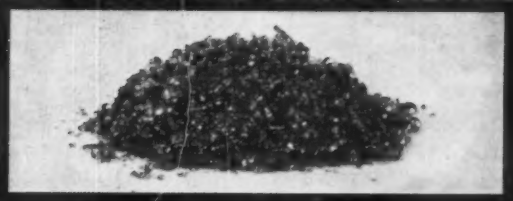

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Circle 2483 on Page 48-B

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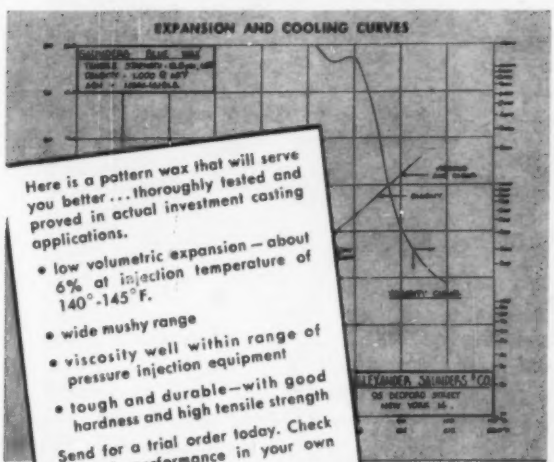

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Circle 2484 on Page 48-B

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Circle 2485 on Page 48-B

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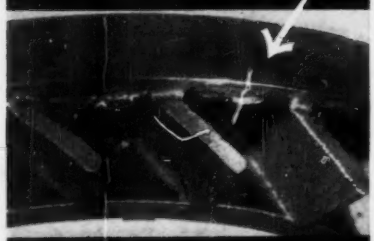

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Circle 2486 on Page 48-B

BEHIND THE BYLINES

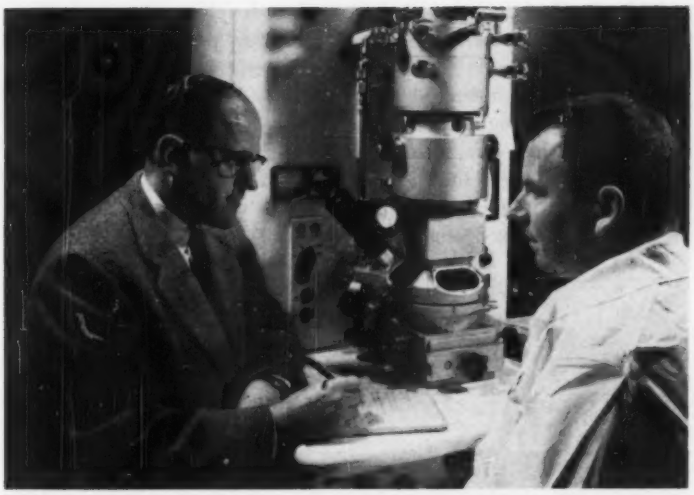
Lewis E. Zwissler, author of "Spinning Makes Stronger Rocket Cases", which leads off this month's issue, knows his subject well — he's associate manager of the Polaris manufacturing and materiel division of Aerojet-General Corp. in Sacramento, producing solid-rocket motors. He has been in the solid-rocket plant since 1958 and, as head of the applied studies department, was responsible for development of materials and fabrication methods used in making Polaris motor cases. Later, as manager of the fabrication development department, he worked on the application of shear spinning to large solid rocket cases as a new fabrication method for ultra-high-strength steels.

A graduate of Armour Insitute of Technology, he received his M.S. degree from Rutgers University, then went on to more graduate work at Illinois Institute of Technology. His career in industry included work on design and fabrication problems in marine and aircraft gas turbines for Elliott Co. and General Electric Co., and work on the early stages of the liquid and solid fuel rocket motors for M. W. Kellogg Co.

"Does Silicon Accelerate Decarburization?" is the question answered by Peter Payson on p. 78. A native New Yorker, he graduated from Columbia College with a B.A. in 1920 and two years later earned his metallurgical engineering degree from Columbia Engineering School. Joining Crucible Steel Co. of America the following year as a metallurgist in the Halcomb Div., he later moved to the Harrison, N. J., plant as manager of the research laboratory, then in 1955 to Pittsburgh as manager of research and development. He is now assistant director of research.

Before moving to Pittsburgh, he was a lecturer in metallurgy at the Graduate School of Stevens Institute of Technology for 14 years.

Electron metallographic studies on a series of carburized and carbo-nitrided steels sparked the article on p. 86 by S. R. Rouze and W. L. Grube (p. 217, top, right to left), both at General Motors' Research Laboratories in Warren, Mich. Mr. Rouze came to G.E. after receiving his degree in engineering physics from the University of Colorado in 1949. His work in the physics department is concerned with electron microscopy and its metallurgical applications, and more recently he has concentrated on high-temperature transformation in metals, using thermionic emission electron miscroscopy for these studies.



Mr. Grube, now assistant head of the physics department, began his tenure with G.M. in 1946 as a member of the microscopy group where he worked on development techniques for electron microscopy and application of electron metallurgy. He was placed in charge of the physics of solids section of the department in 1952, and was named assistant head two years ago. A graduate of Ohio State University, with a degree in engineering physics, he continued his studies on a research fellowship at the Applied Science Laboratory of the University of Cincinnati and was awarded an M.S. degree in engineering in 1942.

Astroloy, the latest addition to the ranks of nickel-base superalloys, was developed by General Electric's Flight Propulsion Div., where both J. F. Barker and W. H. Couts (authors of the article on p. 94, shown, left to right, below) are assigned. R. J. Morris, the third author, formerly with G.E., now works for International Nickel Co. (see "Behind the Bylines", December 1959, p. 231).

Graduating from the University of Cincinnati in 1953 with a metallurgical engineering degree, James Barker soon was called up for service in the U.S. Army Ordnance Corps. After his release from active duty, he joined G.E. as a metallurgical engineer in the flight propulsion laboratory department, then transferred to the

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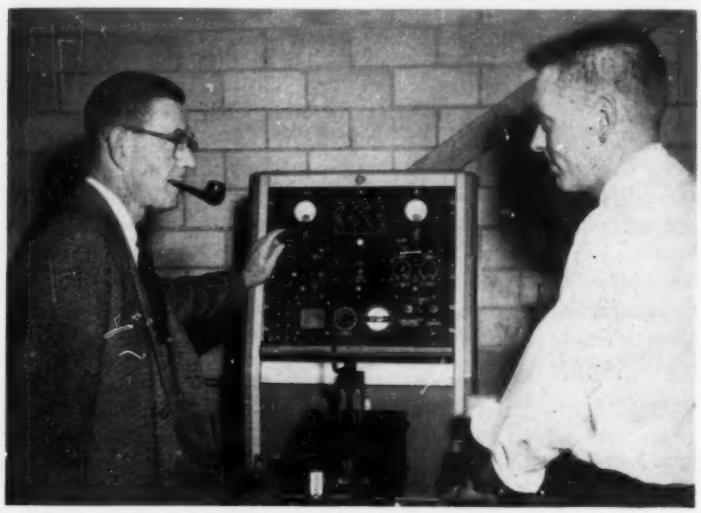
large jet engine department as an alloy development engineer in the structural materials unit, working on new precipitation hardening nickel-base sheet alloys and high-temperature nickel-base alloys.

Wilford Couts studied at the University of Illinois (B.S. degree in metallurgical engineering), then went on to graduate studies at Ohio State University. Before joining G.E., he was a metallography and project engineer for Battelle Memorial Institute; since coming to the large jet engine department, he has worked on the development of René 41 and other superalloys.

● ● ●

Eight nondestructive testing methods are covered in the article on p. 110 by two members of Superior Tube Co.'s metallurgical department — A. M. Bounds and J. R. Grieve (left to right, below). Mr. Bounds has been chief metallurgist at Superior Tube for more



than 26 years. Following his graduation from Lehigh University in 1933, he was a research fellow assistant at the University, receiving his M.S. degree in metallurgical engineering two years later.

The junior member of the author team came to Superior late last summer to be in charge of nondestructive testing development for small tubing. Born in Glasgow, Scotland, he served four years in the U.S. Army, then went on to study at Stevens Institute of Technology where he received a degree in mechanical engineering in 1958. He was supervisor of nondestructive testing at Alco Products Inc., Dunkirk, N. Y., before going to Superior Tube.

● ● ●

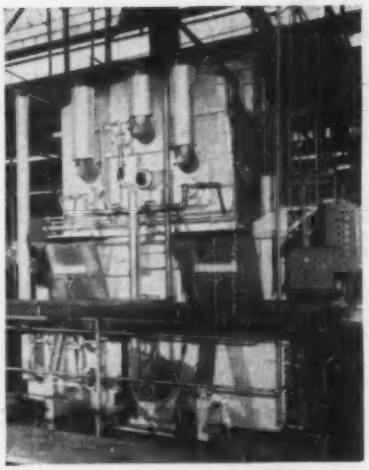
How Union Carbide Chemicals Co. solved its dual corrosion problem (with the help of the Alloy Tube Div. of Carpenter Steel Co.) is told by W. G. Ashbaugh and S. E. Doughty on p. 115. In the corrosion field for 10 of his 12 years with the company, Bill Ashbaugh (right) is now in charge of the corrosion and metallurgical group at Union Carbide Chemicals Co., Texas City, Tex., and

also does consultation work for the Seadrift and Brownsville, Tex., plants. He is responsible for selecting and evaluating materials of construction for chemical processes and for investigating equipment failures. He came to Texas City (where he lives with his wife, Marjorie, and five-year-old son, William Murray) direct from Albion College after his graduation with a degree in chemistry. Other activities include church work (he is a vestryman) and indulgence in his favorite hobby – color photography.

Mr. Doughty's business career has been devoted to the manufacture and sales of stainless steel bars, wire and tubing. He received his degree in metallurgical engineering from Lehigh University in 1939, then worked for Armco until World War II began. After five years in the U.S. Army Ordnance Corps, he was discharged and came to Alloy Tube Div. as chief metallurgist, rising to manager of technical services.

One of the new and promising materials under investigation by the N.A.S.A. – metal reinforced with metallic fibers – is covered in the article on p. 118 by three N.A.S.A. engineers – J. W. Weeton, D. L. McDanels and R. W. Jech (left to right, below). Mr. McDanels has been with N.A.S.A. as a materials research engineer since graduating from Case Institute of Technology in 1957. He has done considerable work on jet engine turbine alloys and is now carrying

on further studies on metal fiber composites. Mr. Jech, who has an engineering degree from Ohio State University (1953), is a materials research engineer working on metal-ceramic composites. J. W. Weeton has been a materials research scientist at the N.A.S.A. Lewis Research Center since 1946 and, as assistant branch chief of the alloys and composite materials branch, is responsible for research. He received his degree in metallurgical engineering from Fenn College in 1944 and an M.S. in physical metallurgy from Case Institute of Technology in 1950.



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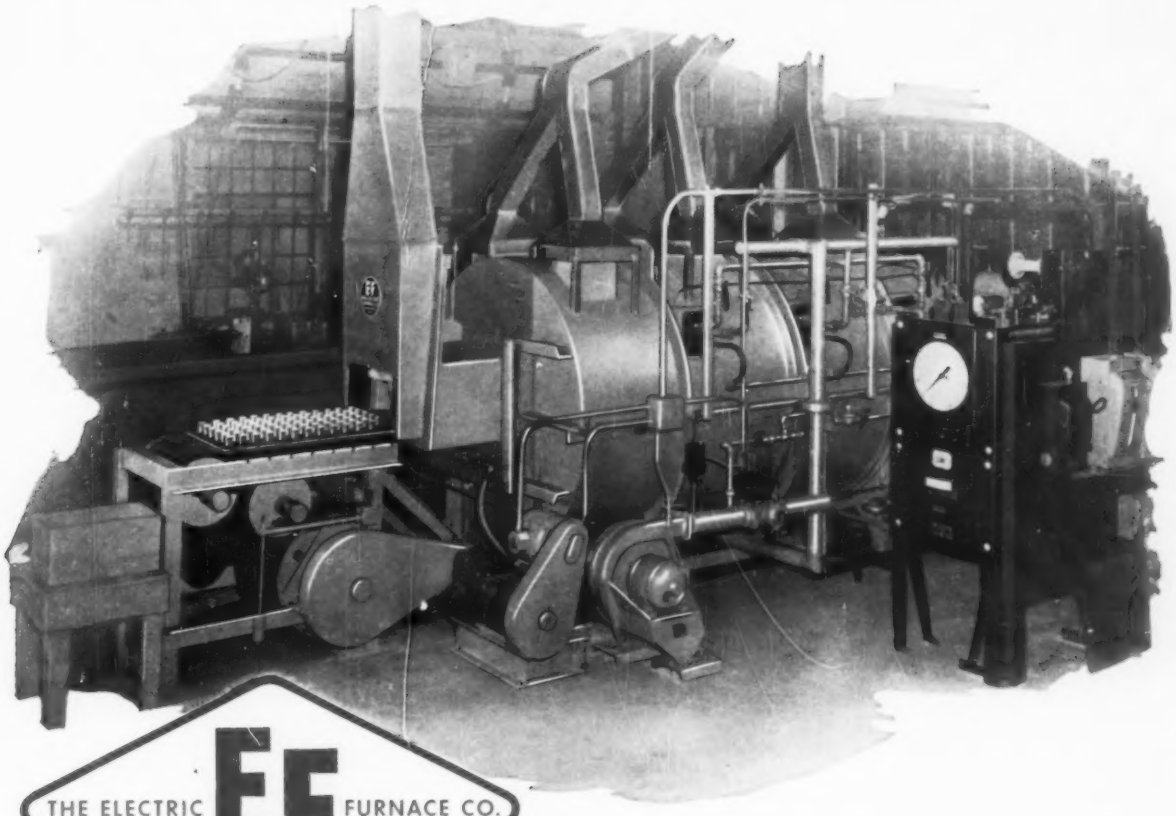

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